John Steele

ELEMENTS

OF

CHEMISTRY.

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THE great experience of M. Chaptal, his unaffected candour, and the perfpicuity which is feen in every part of the following treatife, cannot but render it extenfively ufeful. I have been particularly careful not to diminifh this laft merit, by deviating in any refpect from that fcrupulous attention to accuracy which is indifpenfably required to give authority to the tranflation of a work of fcience.

W. NICHOLSON.

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OF

THE AUTHOR.

AGRICULTURE is no doubt the basis of public welfare, because it alone supplies all the wants which nature has connected with our existence. But the arts and commerce form the glory, the ornament, and the riches of every polished nation; since our refinement, and mutual dependence on each other, have created a new set of wants which require to be supplied. The cultivation of the arts is therefore become almost as necessary as that of the ground; and the true means of securing theſe two foundations of the reputation and proſperity of a ſtate, conſiſt in encouraging the Science of Chemiſtry, which diſcovers their principles. If this truth were not univerſally acknowledged, I might on the preſent occaſion give an account of the ſucceſs with which my labours have been attended in this province*. I might even call upon the public voice; and it would declare that, ſince the eſtabliſhment of lectures on chemiſtry, between three and four hundred perſons have every year derived advantage from inſtructions in this ſcience. It is well known that our ancient ſchools of medicine and ſurgery, whoſe ſucceſs and ſplendour are connected with the general intereſt of this province, are more flouriſhing and more numerous ſince that period. And with the ſame confidence I might appeal to the Public, that our manufactures are daily increaſing in perfection; that ſeveral new kinds of induſtry have been introduced into Languedoc; that, in a regular ſucceſſion, abuſes have been reformed in the manufactories, while the proceſſes of the arts

* Languedoc.

have

have been ſimplified; that the number of coal-mines actually wrought is increaſed; and that, upon my principles, and in conſequence of my care and attention, manufactories of alum, of oil of vitriol, of copperas, of brown red, of artificial pozzolana, of ceruſe, of white lead, and others, have been eſtabliſhed in ſeveral parts of the province.

Chemiſtry is therefore eſſentially connected with the reputation and proſperity of a ſtate; and at this peculiar inſtant, when the minds of men are univerſally buſied in ſecuring the public welfare, every citizen is accountable to his country for all the good which his peculiar ſituation permits him to do. Every one ought to haſten, and preſent to ſociety the tribute of thoſe talents which heaven has beſtowed on him; and there is no one who is not able to bring ſome materials, and depoſit them at the foot of the ſuperb edifice which the virtuous adminiſtrators are raiſing for the welfare of the whole. It is with theſe views that I have preſumed to offer to my countrymen the work which I at preſent publiſh;

liſh; and I entreat them to exerciſe their ſeverity upon the intention of the author only, but to reſerve all their indulgence to the work.

I publiſh theſe Elements of Chemiſtry with the greater confidence, becauſe I have had opportunities myſelf of obſerving the numerous applications of the principles which conſtitute its baſis to the phenomena of nature and art. The immenſe eſtabliſhment of chemical products which I have formed at Montpellier has allowed me to purſue the development of this doctrine, and to obſerve its agreement with all the facts which the various operations preſent to us. It is this doctrine alone which has led me to ſimplify moſt of the proceſſes, to bring ſome of them to perfection, and to rectify all my ideas. It is therefore with the moſt intimate confidence that I propoſe it. I find no difficulty in making a public acknowledgment that I have for ſome time taught a different doctrine from that which I at preſent offer. I then believed it to be true and ſolid; but I did not on that account ceaſe to conſult nature.

nature. I have conſtantly entered into this reſearch with a mind eager for improvement. Natural truths were capable of fixing themſelves with all their purity in my mind, becauſe I had baniſhed prejudice; and inſenſibly I found myſelf drawn by the force of facts to the doctrine I now teach. Let other principles impreſs the ſame conviction on my mind; let the ſame number of phenomena and facts exhibit themſelves in their favour; the ſame number of happy applications to the operations of nature and of art; let them appear to my mind with all the ſacred characters of truth; and I will publiſh them with the ſame zeal, and with the ſame intereſt. I condemn equally the man who, attached to the ancient notions, reſpects them ſo much as to reject without mature examination every thing which appears to oppoſe them; and him who embraces with enthuſiaſm, and almoſt without reflection, the principles of any new doctrine. Both are worthy of compaſſion if they grow old in their prejudices; and both are worthy of blame if they perpetuate them.

I have been careful to baniſh all diſcuſſions from my work. That ſpirit of party which but too often cauſes a diviſion between perſons who are purſuing the ſame objects, that tone of bitterneſs which predominates in certain diſputes, that want of candour which is inſenſibly produced by the movements of ſelf-love, have but too long retarded the progreſs of our knowledge. The love of truth is the only paſſion which a philoſopher ought to indulge. The ſame object, the ſame intereſt, tend to unite chemiſts. Let the ſame ſpirit inſpire them, and direct all their labours. Then we ſhall ſoon behold chemiſtry advancing in a rapid progreſs; and its cultivators will be honoured with the ſuffrage and the gratitude of their countrymen.

I have endeavoured in this work to explain my ideas with clearneſs, preciſion, and method. I know by experience that the ſucceſs of any work, and its various degrees of utility, often depend on the form under which the doctrine which it contains is diſplayed; and it has accordingly been my intention to ſpare no pains

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in exhibiting the truths which form the bafis of this work in all the characters they are juftly entitled to.

In compofing thefe Elements of Chemiftry, I have availed myfelf with advantage of all the facts which I have found in the works of the celebrated chemifts who adorn this age. I have even made no fcruple to follow their method in drawing up certain articles; and have transferred into my own work, almoft without alteration, thofe facts which I have elfewhere found defcribed with a greater degree of precifion and perfpicuity than I might have been capable of beftowing on them. This proceeding, in my opinion, renders homage to authors, inftead of robbing them. If fuch a proceeding might juftify reclamations, Meffrs. Lavoifier, De Morveau, Berthollett, De Fourcroy, Sage, Kirwan, &c. might eafily declare againft me.

I was well aware that the pretenfion of knowing, difcuffing, and methodically diftributing the whole of our prefent fcience of chemiftry, was an enterprife beyond my

ability.

ability. This ſcience has made ſo great a progreſs, and its applications are ſo multiplied, that it is impoſſible to attend to the whole with the ſame care: and it appears to me that the writer of an elementary work ought at preſent to attend principally to the development of general principles, and content himſelf in pointing out the conſequences, and their applications. In this way of proceeding we ſhall follow the method which has long been practiſed in the ſtudy of the mathematics; the principles of which, nearly inſulated, and ſeparated from all application, form the firſt ſtudy of him who means to acquire them.

To obtain a thorough acquaintance with all the knowledge which has been acquired in chemiſtry until our time, the chemical part of the Encyclopédie Méthodique may be conſulted. In this work, the celebrated author gives the moſt intereſting account of the progreſs of the ſcience. Here it is that he diſcuſſes the ſeveral opinions with that candour and energy which become the man of letters whoſe mind is directed to truth only.

Here

Here it is that he has made a precious depoſit of all the knowledge yet acquired, in order to preſent to us in the ſame point of view all which has been done, and all which remains to be done; and here, in a word, it is that Mr. De Morveau has rendered the moſt ſtriking homage to the truth of the doctrine we now teach; becauſe, after having combated ſome of its principles in the firſt volume, he has had the courage to recant, the moment the facts ſeen in a better point of view, and repeated experiments, had ſufficiently enlightened him. This great example of courage and candour is doubtleſs honourable to the learned man who gives it; but it cannot fail to add ſtill more to the confidence which may be placed in the doctrine which is its object.

The development of the principles upon which the New Nomenclature is eſtabliſhed, may be found in the Elementary Treatiſe of Chemiſtry of Mr. Lavoiſier; and I refer likewiſe to this excellent work for the figure and explanation of all the apparatus I ſhall have occaſion to ſpeak

of.

of. I take this ſtep the more earneſtly, becauſe, by aſſociating my own productions to thoſe of this celebrated chemiſt, I entertain the hope of ſecuring their ſucceſs, and can deliver them into the hands of the public with greater confidence.

PRE-

PRELIMINARY DISCOURSE.

IT appears that the ancient nations poſſeſſed ſome notions of chemiſtry. The art of working metals, which dates from the moſt remote antiquity; the luſtre which the Phœnicians gave to certain colours; the luxury of Tyre; the numerous manufactures which that opulent city included within its walls—all announce a degree of perfection in the arts, and ſuppoſe a conſiderable extent and variety of chemical knowledge. But the principles of this ſcience were not then united into a body of doctrine; they were concentrated in the workſhops of the manufacturers, where they had their origin; and obſervations alone, tranſmitted from one operator to another,

another, enlightened and conducted the steps of the artist. Such, no doubt, has been the origin of all the sciences. At first they presented unconnected facts ; truths were confounded with error; time and genius alone could clear up the confusion; and the progress of information is always the fruit of slow and painful experiment. It is difficult to point out the precise epocha of the origin of chemical science; but we find traces of its existence in the most remote ages. Agriculture, mineralogy, and all the arts which are indebted to it for their principles, were cultivated and enlightened. We behold the original nations, immediately succeeding the fabulous ages, surrounded by all the arts which supplied their wants ; and we may compare chemistry to that famous river whose waters fertilize the lands they inundate, but whose sources are still to us unknown.

Egypt, which appears to have been the nurse of chemistry reduced to principles, was not slow in turning the applications of this science towards a chimerical end. The first seeds of chemistry were soon changed by by the paſſion of making gold. In a moment all the labours of operators were directed towards alchemy alone; the great object of ſtudy became fixed on an endeavour to interpret fables, alluſions, hieroglyphics, &c.; and the induſtry of ſeveral centuries was conſecrated to the enquiry after the philoſopher's ſtone. But though we admit that the alchemiſts have retarded the progreſs of chemiſtry, we are very far from being diſpoſed to any outrage on the memory of theſe philoſophers: we allow them the tribute of eſteem to which on ſo many accounts they are entitled. The purity of their ſentiments, the ſimplicity of their manners, their ſubmiſſion to Providence, and their love for the Creator, penetrate with veneration all thoſe who read their works. The profoundeſt views of genius are every where ſeen in their writings, allied with the moſt extravagant ideas. The moſt ſublime truths are degraded by applications of the moſt ridiculous nature; and this aſtoniſhing contraſt of ſuperſtition and philoſophy, of light and darkneſs, compels us to admire them, even at the inſtant that

that we cannot withhold our cenfure. We muft not confound the fect of alchemifts, of whom we fhall proceed to fpeak, with that crowd of impoftors, that fordid multitude of operators at the furnace, whofe refearches were directed to the difcovery of minds capable of being impofed on, who fed the ambition of fuch weak minds by the deceitful hope of increafing their riches. This laft clafs of vile and ignorant men has never been acknowledged by the true alchemifts; and they are no more entitled to that name, than the vender of fpecifics on the ftage to the honourable name of Phyfician.

The hope of the alchemift may indeed be founded on a flender bafis; but the great man, the man of genius, even at the time when he is purfuing an imaginary object, knows how to profit by the phenomena which may prefent themfelves, and derives from his labours many ufeful truths which would have efcaped the penetration of ordinary men. Thus it is that the alchemifts have fucceffively enriched pharmacy and the arts with moft of their compofitions. The ftrong defire of acquiring riches has in all

all times been a paſſion ſo general, that this ſingle motive has been ſufficient to lead many perſons to the cultivation of a ſcience which has more relation than any other to metals; which ſtudies their nature more particularly, and appears to facilitate the means of compoſing them. It is known that the Abdarites did not begin to conſider the ſciences as an occupation worthy a reaſonable man, until they had ſeen a celebrated philoſopher enrich himſelf by ſpeculations of commerce; and I do not doubt but that the deſire of making gold has decided the vocation of ſeveral chemiſts. We are therefore indebted to alchemy for ſeveral truths, and for ſeveral chemical profeſſors: but this obligation is ſmall, in compariſon to the maſs of uſeful truth which might have been afforded during the courſe of ſeveral centuries; if, inſtead of endeavouring to form the metals, the operations of chemiſts had been confined to analyſing them, ſimplifying the means of extracting them, combining them together, working them, and multiplying and rectifying their uſes.

The rage for making gold was ſucceeded by by the seductive hope of prolonging life by means of chemistry. The persuasion was easily admitted, that a science which affords remedies for all disorders, might without effort succeed in affording a universal medicine. The relations which have been handed down to us of the long life of the ancients, appeared to be a natural effect of their knowledge in chemistry. The numerous fables of antiquity obtained the favour of being admitted among established facts; and the alchemists, after having exhausted themselves in the search after the philosopher's stone, appeared to redouble their efforts to arrive at an object still more chimerical. At this period the elixirs of life, the arcana, the polychrest medicines, had their origin; together with all those monstrous preparations, of which a few have been handed down even to our days.

The chimera of the universal medicine agitated the minds of most men in the sixteenth century; and immortality was then promised with the same effrontery as a Charlatan now announces his remedy for every disease. The people are easily seduced by these thefe ridiculous promifes; but the man of knowledge can never be led to think that chemiftry can fucceed in reverfing that general law of nature which condemns all living beings to renovation, and a continual circulation of decompofitions and fucceffive generations. This fect gradually became an object of contempt. The enthufiaft Paracelfus, who, after having flattered himfelf with immortality, died at the age of forty-eight at an inn at Saltfburg, completed its difgrace. From that moment the fcattered remains of this fect united themfelves, never more to appear again in public. The light which began to fhine forth on all fides, rendered it neceffary that they fhould have recourfe to fecrecy and obfcurity; and thus at length chemiftry became purified.

James Barner, Bohnius, Tachenius, Kunckel, Boyle, Crollius, Glafer, Glauber, Schroder, &c. appeared on the ruins of thefe two fects, to examine this indigefted aggregate, and feparate from the confufed mafs of phenomena, of truth and of error, every thing which could tend to enlighten the fcience. The fect of the adepts, urged on by the madness of immortality, had discovered many remedies; and pharmacy and the arts then became enriched with formulæ and compositions, whose operations required only to be rectified, and their applications better estimated.

Nearly at the same time appeared the celebrated Becher. He withdrew chemistry from the too narrow limits of pharmacy. He shewed its connection with all the phenomena of nature; and the theory of the formation of metals, the phenomena of fermentation, the laws of putrefaction, were all comprehended and developed by this superior genius. Chemistry was then directed to its true object: and Stahl, who succeeded Becher, reduced to certain general principles all the facts with which his predecessor had enriched the science. He spoke a language less enigmatical; he classed all the facts with order and method; and purged the science of that alchemic infection, to which Becher himself was too much attached. But if we consider how great are the claims of Stahl, and how few the additions which have been made to his doc-

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trine until the middle of this century, we cannot but be aftonifhed at the fmall progrefs of the fcience. When we confult the labours of the chemifts who have appeared fince the time of Stahl, we fee moft of them chained down to the fteps of this great man, blindly fubfcribing to all his ideas; and the labour of thinking appeared no longer to exift among them. Whenever a well-made experiment threw a gleam of light unfavourable to his doctrine, we fee them torment themfelves in a ridiculous manner to form a delufive interpretation. Thus it was that the increafe of weight which metals acquire by calcination, though little favourable to the idea of the fubtraction of a principle without any other addition, was neverthelefs incapable of injuring this doctrine.

The almoft religious opinion which enflaved all the chemifts to Stahl, has no doubt been pernicious to the progrefs of chemiftry. But the ftrong defire of reducing every thing to firft principles, and of eftablifhing a theory upon incomplete experiments, or facts imperfectly feen, did not admit of the fmalleft obftacles. From the moment that analysis had shewn some of the principles of bodies, the chemist thought himself in possession of the first agents of nature. He considered himself as authorized to regard those bodies as elements which appeared no longer susceptible of being decomposed. The acids and the alkalis performed the principal part in natural operations: and it appeared to be a truth buried in oblivion, that the term where the artist stops is not the point at which the Creator has limited his power; and that the last result of analysis does indeed mark the limits of art, but does not fix those of nature. We might likewise reproach certain chemists for having too long neglected the operations of the living systems. They confined themselves in their laboratories, studied no bodies but in their lifeless state, and were incapable of acquiring any knowledge but such as was very incomplete: for he who, in his researches, has no other object in view than that of ascertaining the principles of a substance, acts like a physician who should suppose he had acquired a complete notion of the human body by

confining

confining his ftudies to the dead carcafe. But we muft likewife obferve that, in order to form a proper notion of the phenomena of living bodies, it is neceffary to poffefs the means of confining the gafeous principles which efcape from bodies; and of analyfing thefe volatile and invifible fubftances which combine together. Now this work was impoffible at that time; and we ought to beware of imputing to men thofe errors which arife from the ftate of the times in which they lived.

It may perhaps be demanded, on this occafion, why chemiftry was fooner known, and more generally cultivated, in Germany and in the North than in our kingdom. I think that many reafons may be given for this. In the firft place, the fcholars of Stahl and of Becher muft have been more numerous, and confequently their inftruction farther extended. Secondly, the working of mines having become a refource neceffary to the governments of the North, has been fingularly encouraged; and that chemiftry which enlightens mineralogy muft neceffarily sarily have participated in its encouragements *.

The study of chemistry did not begin to be cultivated to advantage in France until the end of the last century. The first wars of Louis XIV. so proper to develop the talents of the artist, the historian, and the military man, appeared little favourable to

* Since the French government has facilitated the study of mineralogy by the most superb establishments, we have beheld the taste for chemistry revive, the arts which have the working of metals for their object have been rendered more perfect, and the mines which have been wrought are more numerous. Mr. Sage has been more particularly assiduous and zealous to turn the favour of government towards this object. I have been a witness to the laborious attention of this chemist to effect this revolution. I have beheld the personal sacrifices he made to bring it forward. I have applauded his zeal, his motives, and his talents. The same sentiments still occupy my mind; and though I teach a doctrine at present which is different from his, this circumstance arises from the impossibility of commanding opinions. The philosopher who is truly worthy of this name, is capable of distinguishing the friend of his art from the slave of his system: and, in a word, every one ought to write according to his conviction; the most sacred axiom of the sciences being, "Amicus Plato, sed magis amica veritas."

the peaceable study of nature. The naturalist who in his researches sees union and harmony around him, cannot be an indifferent spectator of the continual scenes of disorder and destruction; and his genius is crushed in the midst of troubles and agitations. The mind of the great Colbert, deeply penetrated with these truths, quickly endeavoured to temper the fire of discord, by turning the minds of men towards the only objects which could secure the peace and prosperity of the state. He exerted himself to render trade flourishing: he established manufactories: learned men were invited from all parts, encouraged, and united together, to promote his vast projects. Then it was that the ardour of enquiry replaced for a time the fury of conquest; and France very soon stood in competition with all nations for the rapid progress of the sciences, and the perfection of the arts. Lemery, Homberg, and Geoffroy arose nearly at the same time; and other nations were no longer entitled to reproach us for the want of chemists. From that moment the existence of the arts appeared to be well assured. All the

the ſciences which afford their firſt principles, were cultivated with the greateſt ſucceſs: and it will ſcarcely be credited that, in the ſpace of a few years, the arts were drawn from a ſtate of non-entity; and carried to ſuch a degree of perfection, that France, which had before received every thing from foreign countries, became in poſſeſſion of the glory of ſupplying its neighbours with models and with merchandizes.

Chemiſtry and natural hiſtory, however, at the beginning of this century, were cultivated only by a very ſmall number of perſons; and it was then thought that the ſtudy of theſe ſciences ought to be confined to the academies. But two men, whoſe names will be ever famous, have rendered the taſte general under the reign of Louis XV. The one poſſeſſed that noble ſpirit which is a ſtranger to the power of prejudice, that indefatigable ardour which ſo eaſily overcomes every obſtacle, that openneſs of character which inſpires confidence, and transfuſed into the minds of his pupils that enthuſiaſm of which he himſelf felt the force. While Rouelle enlightened the ſcience of chemiſtry, chemiftry, Buffon prepared a revolution ftill more aftonifhing in natural hiftory. The naturalifts of the North had fucceeded in caufing their productions to be read by a fmall number of the learned; but the works of the French naturalift were foon, like thofe of nature, in the hands of the whole world. He poffeffed the art of diffufing through his writings that lively intereft, that enchanting colouring, and that delicate and vigorous touch, which influence, attach, and fubdue the mind. The profundity of his reafoning is every where united to all that agreeable illufion which the moft brilliant imagination can furnifh. The facred fire of genius animates all his productions; his fyftems conftantly exhibit the moft fublime profpects in their totality, and the moft perfect correfpondence in their minute parts; and, even when he exhibits mere hypothefes, we are inclined to perfuade ourfelves that they are eftablifhed truths. We become like the artift who, after having admired a beautiful ftatue, ufed his efforts to perfuade himfelf that it refpired, and removed every thing which could

could diſſipate his illuſion. We take up his work with a pleaſure reſembling that of the man who turns again to ſleep, in hopes of prolonging the deception of an agreeable dream.

These two celebrated men, by diffuſing the taſte for chemiſtry and natural hiſtory, by making their relations and uſes better known, conciliated the favour of government towards them; and from that moment every one intereſted himſelf in the progreſs of both ſciences. Thoſe perſons who were beſt qualified in the kingdom, haſtened to promote the revolution which was preparing. The ſciences ſoon inſcribed in their liſt of cultivators the beloved and reſpected names of La Rochefoucault, Ayen, Chaulnes, Lauraguais, Maleſherve, &c.; and theſe men, diſtinguiſhed by their birth, were honoured with a new ſpecies of glory, which is independent of chance or prejudice. They enriched chemiſtry with their diſcoveries, and aſſociated their names with all the other literati who purſued the ſame career. They revived in the mind of the chemiſt that paſſion for glory, and that ardour

ardour for the public good, which continually excite new efforts. The man of ambition and intrigue no longer endeavoured to deprefs the modeft and timid man of genius. The credit of men in place ferved as a defence and fupport againft calumny and perfecution. Recompenfes were affigned to merit. Learned men were difpatched into all parts of the world, to ftudy the arts, and collect their productions. Men of the firft merit were invited to inftruct us with regard to our own proper riches; and eftablifhments of chemiftry which were made in the principal towns of the kingdom, diffufed the tafte for this fcience, and fixed among us thofe arts which we might in vain have attempted to naturalize, if a firm bafis had not been firft laid. The profeffors eftablifhed in the capital, and in the provinces, appeared to be placed between the academies and the people, to prepare the latter for thofe truths which flow from fuch refpectable affociations. We may confider them as a medium which refracts and modifies the rays of light that iffue from thofe various luminous centres; and directs them towards

towards the manufactories, to enlighten and improve their practice. Without thefe favours, without this confideration and thefe recompenfes, could it have been expected that the moft unaffuming among philofophers would have exerted himfelf to promote the reputation of a people to whom he was unknown? Could a man fo fituated reafonably hope to fucceed in carrying a difcovery into effect? Is it probable that he fhould have poffeffed a fufficient fortune to work in the large way, and by this means alone to overcome the numberlefs prejudices which banifh men of fcience from manufactories? The contemplative fciences demand of the fovereign repofe and liberty only; but experimental fciences demand more, for they require affiftance and encouragement. What indeed could be hoped in thofe barbarous ages, wherein the chemift fcarcely durft avow the nature of the occupation which in fecret conftituted his greateft pleafure? The title of Chemift was almoft a reproach: and the prejudice which confounded the profeffors of this fcience with fuch wretched ed projectors as are entitled only to pity, has probably kept back the revival of the arts for several centuries; for chemistry alone can afford them a proper basis. If the princes of past times had been friends of the arts, and jealous to acquire a pure and durable reputation; if they had been careful to honour the learned, to collect their valuable labours, and to transmit to us without alteration the precious annals of human genius; we should have been dispensed from labouring among the rubbish of early times, to consult a few of those remains which have escaped the general wreck; and we should have been spared the regret of allowing, after many useful researches, that the master-pieces of antiquity which remain answer scarcely any other purpose than to give us an idea of that superiority to which the earlier nations had arrived. Time, the sword, fire, and prejudice have devoured all; and our researches serve only to add to our regret for the losses which the world has sustained.

The science of chemistry possesses the glory, in our days, not only of having obtained

tained the protection of government, but it may likewiſe boaſt of another equally elevated. This ſcience has fixed the attention, and formed the occupation, of various men in whom the habit of a profound ſtudy of the accurate ſciences had produced a neceſſity of admitting nothing but what is proved, and of attaching themſelves only to ſuch branches of knowledge as are ſuſceptible of ſtrict proof. Meſſrs. De la Grange, Condorcet, Vander Monde, Monge, De la Place, Meuſnier, Couſin, the moſt celebrated mathematicians of Europe, are all intereſted in the progreſs of this ſcience, and moſt of them daily add to its progreſs by their diſcoveries.

So great a maſs of inſtruction, and ſuch ample encouragement, could not but effect a revolution in the ſcience itſelf; and we are indebted to the combined efforts of all theſe learned men for the diſcovery of ſeveral metals, the creation of various uſeful arts, the knowledge of a number of advantageous proceſſes, the working of ſeveral mines, the analyſis of the gaſes, the decompoſition of water, the theory of heat, the

the doctrine of combustion; and a mass of knowledge so absolute and so extended, respecting all the phenomena of art and of nature, that in a very short time chemistry has become a science entirely new. We might now say with much more truth what the celebrated Bacon affirmed of the chemistry of his time: "A new philosophy," says he, "has issued from the furnaces of "the chemists, which has confounded all "the reasonings of the ancients."

But while discoveries became infinitely multiplied in chemistry, the necessity of remedying the confusion which had so long prevailed, was soon seen, and indicated the want of a reform in the language of this science. There is so intimate a relation between words and facts, that the revolution which takes place in the principles of a science ought to be attended with a similar revolution in its language: and it is no more possible to preserve a vicious nomenclature with a science which becomes enlightened, extended, and simplified, than to polish, civilize, and instruct uninformed man without making any change in his natural

tural language. Every chemiſt who wrote on any ſubject was ſtruck with the inaccuracy of the words in common uſe, and conſidered himſelf as authorized to introduce ſome change; inſomuch that the chemical language became inſenſibly longer, more confuſed, and more unpleaſant. Thus the carbonic acid has been known, during the courſe of a few years, under the names of Fixed Air, Aerial Acid, Mephitic Acid, Cretaceous Acid, &c.; and our poſterity may hereafter diſpute whether theſe various denominations were not applied to different ſubſtances. The time was therefore come in which it was neceſſary to reform the language of chemiſtry: the imperfections of the ancient nomenclature, and the diſcovery of many new ſubſtances, rendered this revolution indiſpenſable. But it was neceſſary to defend this revolution from the caprice and fancy of a few individuals; it was neceſſary to eſtabliſh this new language upon invariable principles; and the only means of inſuring this purpoſe was doubtleſs that of erecting a tribunal in which chemiſts of acknowledged merit ſhould

ſhould diſcuſs the words received without prejudice and without intereſt; in which the principles of a new nomenclature might be eſtabliſhed and purified by the ſevereſt logic: and in which the language ſhould be ſo well identified with the ſcience, the word ſo well applied to the fact, that the knowledge of the one ſhould lead to the knowledge of the other. This was executed in 1788 by Meſſrs. De Morveau, Lavoiſier, Berthollet, and De Fourcroy.

In order to eſtabliſh a ſyſtem of nomenclature, bodies muſt be conſidered in two different points of view, and diſtributed into two claſſes; namely, the claſs of ſimple ſubſtances reputed to be elementary, and the claſs of combined ſubſtances.

1. The moſt natural and ſuitable denominations which can be aſſigned to ſimple ſubſtances, muſt be deduced from a principal and characteriſtic property of the ſubſtance intended to be expreſſed. They may likewiſe be diſtinguiſhed by words which do not preſent any preciſe idea to the mind. Moſt of the received names are eſtabliſhed on this laſt principle, ſuch as the names

Sulphur, Phoſphorus, which do not convey any ſignification in our language, and produce in our minds determinate ideas only, becauſe uſage has applied them to known ſubſtances. Theſe words, rendered ſacred by uſe, ought to be preſerved in a new nomenclature; and no change ought to be made, excepting when it is propoſed to rectify vicious denominations. In this caſe the authors of the New Nomenclature have thought it proper to deduce the denomination from the principal characteriſtic property of the ſubſtance. Thus, pure air might have been called Vital Air, Fire Air, or Oxigenous Gas; becauſe it is the baſis of acids, and the aliment of reſpiration and combuſtion. But it appears to me that this principle has been in a ſmall degree departed from when the name of Azotic Gas was given to the atmoſpherical mephitis—1. Becauſe, none of the known gaſeous ſubſtances excepting vital air being proper for reſpiration, the word Azote agrees with every one of them except one; and conſequently this denomination is not founded upon an excluſive property, diſtinctive and cha-

characteristic of the gas itself. 2. This denomination being once introduced, the nitric acid ought to have been called Azotic Acid, and its combinations Azotates; because the acids are proposed to be denoted by the name which belongs to their radical. 3. If the denomination of Azotic Gas does not agree with this aëriform substance, the name of Azote agrees still less with the concrete and fixed substance; for in this state all the gases are essentially azotes. It appears to me therefore that the denomination of Azotic Gas is not established according to the principles which have been adopted; and that the names given to the several substances of which this gas constitutes one of the elements, are equally removed from the principles of the Nomenclature. In order to correct the Nomenclature on this head, nothing more is necessary than to substitute to this word a denomination which is derived from the general system made use of; and I have presumed to propose that of Nitrogene Gas. In the first place, it is deduced from the characteristic and exclusive property of

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this gas, which forms the radical of the nitric acid. By this means we ſhall preſerve to the combinations of this ſubſtance the received denominations, ſuch as thoſe of the Nitric Acid, Nitrates, Nitrites, &c. In this manner the word which is afforded by the principles adopted by the celebrated authors of the Nomenclature, cauſes every thing to return into the order propoſed to be eſtabliſhed.

2. The method made uſe of to aſcertain the denominations ſuitable to compound ſubſtances, appears to me to be ſimple and accurate. It has been thought that the language of this part of ſcience ought to preſent the analyſes; that the words ſhould be only the expreſſion of facts; and that conſequently the denomination applied by a chemiſt to any ſubſtance which has been analyſed, ought to render him acquainted with its conſtituent parts. By following this method, the Nomenclature is as it were united, and identified with the ſcience; and facts and words agree together. Two things are therefore united, which until this time appeared to have no mutual relation,

lation, the word, and the ſubſtance which it repreſented; and by this means the ſtudy of chemiſtry is ſimplified. But when we apply theſe inconteſtable principles to the various objects of chemiſtry, we ought to follow the analyſis ſtep by ſtep, and upon this ground alone eſtabliſh general and individual denominations. We ought to obſerve, that it is from this analytical method that the various denominations have been aſſigned, and that the methodical diſtributions of natural hiſtory have been at all times made. If man were to open his eyes for the firſt time upon the various beings which people or compoſe this globe, he would eſtabliſh their relation upon the compariſon of their moſt evident properties, and no doubt would found his firſt diviſions upon the moſt ſenſible differences. The various modes of exiſtence, or their ſeveral degrees of conſiſtence, would form his firſt diviſion; and he would arrange them under the heads of ſolid, liquid, or aëriform bodies. A more profound examination, and a more connected analyſis of the individuals, would ſoon convince him that the ſubſtances

ſtances which certain general relations had induced him to unite in the ſame claſs, under a generic denomination, differed very eſſentially among each other, and that theſe differences neceſſarily required ſubdiviſions. Hence he would divide his ſolid bodies into ſtones, metals, vegetable ſubſtances, animal ſuſtances, &c.; his liquids would be divided into water, vital air, inflammable air, mephitic air, &c. When he proceeded to carry his reſearches on the nature of theſe ſubſtances ſtill farther, he would perceive that moſt of the individuals were formed by the union of ſimple principles; and here it is that his applications of the ſyſtem to be followed, in aſſigning a ſuitable denomination to each ſubſtance, would begin. To anſwer this purpoſe, the authors of the New Nomenclature have endeavoured to exhibit denominations which may point out the conſtituent principles. This admirable plan has been carried into execution as far as relates to ſubſtances which are not very complicated, ſuch as the combinations of the principles with each other; the acids, earths, metals, alkalis, &c. And this

this part of the Nomenclature appears to me to leave nothing more to be desired. The explanation may be seen in the work published on this subject by the authors, and in the Elementary Treatise of Chemistry of Mr. Lavoisier. I shall therefore do nothing more in this place than present a sketch of the method I have followed; taking for example the combinations of acids, which form the most numerous class of compounds.

The first step consisted in comprehending under a general denomination the combination of an acid with any given basis; and in order to observe a more exact arrangement, and at the same time to assist the memory, one common termination has been given to all words which denote the combination of an acid. Hence the words Sulphates, Nitrates, Muriates, are used to denote combinations of the sulphuric, nitric, and muriatic acids. The kind of combination is denoted by adding to the generic word the name of the body which is combined with the acid; thus, the sulphate of pot-ash expresses the combination

bination of the ſulphuric acid with potaſh.

The modifications of theſe ſame acids, dependent on the proportions of their conſtituent principles, form ſalts different from thoſe we have juſt ſpoken of; and the authors of the New Nomenclature have expreſſed the modifications of the acids by the termination of the generic word. The difference in the acids ariſes almoſt always from the greater or leſs abundance of oxigene. In the firſt caſe, the acid aſſumes the epithet of Oxigenated; hence the oxigenated muriatic acid, the oxigenated ſulphuric acid, &c. In the ſecond caſe, the termination of the word which denotes the acid, ends in *ous*; hence the ſulphureous acid, the nitrous acid, &c. The combinations of theſe laſt form ſulphites, nitrites, &c.; the combinations of the former compoſe oxigenated muriates, oxigenated ſulphates, &c.

The combinations of the various bodies which compoſe this globe are not all as ſimple as thoſe here mentioned; and it may be immediately perceived how long and trouble-

troublesome the denominations would be, if attempts were made to bestow a single denomination which should denote the constituent principles of a body formed by the union of five or six principles. In this case, the preference has been given to the received appellation, and no other changes have been admitted but such as were necessary in order to substitute proper appellations instead of those which afforded notions contrary to the nature of the objects they were applied to.

I have adopted this Nomenclature in my lectures, and in my writings; and I have not failed to perceive how very advantageous it is to the teacher, how much it relieves the memory, how greatly it tends to produce a taste for chemistry, and with what facility and precision the ideas and principles concerning the nature of bodies fix themselves in the minds of the auditors. But I have been careful to insert the technical terms used in the arts, or received in society, together with these two denominations. I am of opinion that, as it is impossible to change the language of the people, it it is neceffary to defcend to them, and by that means render them partakers of our difcoveries. We fee, for example, that the artift is acquainted with the fulphuric acid by no other name than that of Oil of Vitriol, though the name of the Vitriolic Acid has been the language of chemifts for a century paft. We cannot hope to be more happy in this refpect than our predeceffors; and, fo far from feparating ourfelves from the artift by a peculiar language, it is proper that we fhould multiply the occafions of bringing us together; fo far from attempting to enflave him by our language, we ought rather to infpire his confidence by learning his terms. Let us prove to the artift that our relations with him are more extended than he imagines; and let us by this intimacy eftablifh mutual correfpondence, and a concurrence of information, which cannot but redound to the advantage of the arts and of chemiftry.

After having explained the principal objections which have retarded the improvement of chemiftry, and the caufes which in our time have accelerated its progrefs,

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we ſhall endeavour to point out the principal applications of this ſcience ; in which attempt, we think, we ſhall ſucceed beſt by caſting a general retroſpect over thoſe arts and ſciences which receive certain principles from it.

Moſt of the arts are indebted to accident for their diſcovery. They are in general neither the fruit of reſearch, nor the reſult of combination, but all of them have a more or leſs evident relation to chemiſtry. This ſcience therefore is capable of clearing up their firſt principles, reforming their abuſes, ſimplifying their operations, and accelerating their progreſs.

Chemiſtry bears the ſame relation to moſt of the arts, as the mathematics have to the ſeveral parts of ſcience which depend on their principles. It is poſſible, no doubt, that works of mechaniſm may be executed by one who is no mathematician; and ſo likewiſe it is poſſible to dye a beautiful ſcarlet without being a chemiſt: but the operations of the mechanic, and of the dyer, are not the leſs founded upon invariable

variable principles, the knowledge of which would be of infinite utility to the artist.

We continually hear in manufactories of the caprices and uncertainty of operations; but it appears to me that this vague expression owes its birth to the ignorance of the workmen with regard to the true principles of their art. For nature itself does not act with determination and discernment, but obeys invariable laws; and the inanimate substance which we make use of in our manufactures, exhibits necessary effects, in which the will has no part, and consequently in which caprices cannot take place. Render yourselves better acquainted with the materials you work upon, we might say to the artists; study more intimately the principles of your art; and you will be able to foresee, to predict, and to calculate every effect. It is your ignorance alone which renders your operations a continual series of trials, and a discouraging alternative of success and disappointment.

The public, which continually exclaims that experience is better than science, encourages and supports this ignorance on the

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part of the artist; and it will not be remote from our object to attempt to ascertain the true value of these terms. It is very true, for example, that a man who has had a very long experience may perform operations with exactness; but he will always be confined to the mere manipulation. I would compare such a man to a blind person who is acquainted with the road, and can pass along it with ease, and perhaps even with the confidence and assurance of a man who sees perfectly well; but is at the same time incapable of avoiding accidental obstacles, incapable of shortening his way or taking the most direct course, and incapable of laying down any rules which he can communicate to others. This is the state of the artist of mere experience; however long the duration of his practice may have been, as the simple performer of operations.

It may perhaps be replied, that artists have made very important discoveries in consequence of assiduous labour. This is indeed true, but the examples are very scarce; and we have no right to conclude, because we have seen men of genius without any mathematical

thematical theory execute wonderful works of mechaniſm, that the mathematics are not the baſis of mechanics, or that any one has a right to expect to become a great mechanic without a profound ſtudy of mathematical principles.

It appears to be generally admitted at preſent, that chemiſtry is the baſis of the arts: but the artiſt will not derive from chemiſtry all the advantages he has a right to expect, until he has broken through that powerful barrier which ſuſpicion, ſelf-love, and prejudice have raiſed between the chemiſt and himſelf. Such philoſophers as have attempted to paſs this line, have frequently been repelled as dangerous innovators; and prejudice, which reigns deſpotically in manufactories, has not even permitted it to be thought that the proceſſes were capable of improvement.

It is eaſy to ſhew the advantages which the arts might obtain from chemiſtry, by caſting a retroſpect over its applications to each of them in particular.

1. It appears, from the writings of Columella, that the ancients poſſeſſed a conſi-

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derable extent of knowledge reſpecting agriculture, which was at that time conſidered as the firſt and nobleſt occupation of man. But when once the objects of luxury prevailed over thoſe of neceſſity, the cultivation of the ground was left to the mere ſucceſſion of practice, and this firſt of the arts became degraded by prejudices.

Agriculture is more intimately connected with chemiſtry than is uſually ſuppoſed. It muſt be admitted that every man is capable of cauſing ground to bear corn; but what a conſiderable extent of knowledge is neceſſary to cauſe it to produce the greateſt poſſible quantity! It is not enough, for this purpoſe, to divide, to cultivate, and to manure any piece of ground: a mixture is likewiſe required of earthy principles ſo well aſſorted, that it may afford a proper nouriſhment; permit the roots to extend themſelves to a diſtance, in order to draw up the nutritive juices; give the ſtem a fixed baſe; receive, retain, and afford upon occaſion, the aqueous principle, without which no vegetation can be formed. It is therefore eſſential to aſcertain the nature of the earth, the avidity with which it seizes water, its force of retaining it, &c.; and these requisites point to studies which will afford principles not to be obtained by mere practice but slowly and imperfectly.

Every grain requires a peculiar earth. Barley vegetates freely among the dry remains of granite; wheat grows in calcareous earth, &c. And how can it be possible to naturalize foreign products, without a sufficient stock of knowledge to supply them with an earth similar to that which is natural to them?

The disorders of grain and forage, and the destruction of the insects which devour them, are objects of natural history and chemistry: and we have seen in our own times the essential art of drying and preserving grain, and all those details which are interesting in the preparation of bread, carried by the labours of a few chemists to a degree of perfection which seemed difficult to have been attained.

The art of disposing stables in a proper manner, that of choosing water adapted for the drink of domestic animals, the œconomical

cal processes for preparing and mixing their food, the uncommon talent of supplying a proper manure suited to the nature of soils, the knowledge necessary to prevent or to repair the effects of blights—all come within the province of Chemistry; and without the assistance of this science our proceeding would be painful, slow, and uncertain.

We may at present insist upon the necessity of chemistry in the various branches of agriculture with so much the more reason, as government does not cease to encourage this first of arts by recompences, distinctions, and establishments; and the views of the state are forwarded by the proposal of means to render this art flourishing. We see, with the greatest satisfaction, that by a happy return of reflection, we begin to consider agriculture as the purest, the most fruitful, and the most natural source of our riches. Prejudices no longer tend to oppress the husbandman. Contempt and servitude are no longer the inheritance received for his incessant labours. The most useful and the most virtuous clafs of men is likewife that whofe ftate is moft minutely confidered; and the cultivator of the ground in France is at laft permitted to raife his hands in a ftate of freedom to Heaven, in gratitude for this happy revolution.

2. The working of mines is likewife founded upon the principles of chemiftry. This fcience alone points out and directs the feries of operations to be made upon a metal, from the moment of its extraction from the earth until it comes to be ufed in the arts.

Before the chemical analyfis was applied to the examination of ftones, thefe fubftances were all denoted by fuperficial characters, fuch as colour, hardnefs, volume, weight, form, and the property of giving fire with the fteel. All thefe circumftances had given rife to methods of divifion in which every other property was confounded; but the fucceffive labours of Pott, Margraaff, Bergmann, Scheele, Bayen, Dietrich, Kirwan, Lavoifier, De Morveau, Achard, Sage, Berthollett, Gerhard, Erhmann, Fourcroy, Mongez,

Mongez, Klaproth, Crell, Pelletier, De la Metherie, &c. by instructing us concerning the constituent principles of every known stone, have placed these substances in their proper situations, and have carried this part of chemistry to the same degree of precision as that which we before possessed respecting the neutral salts.

The natural history of the mineral kingdom, unassisted by chemistry, is a language composed of a few words, the knowledge of which has acquired the name of Mineralogist to many persons. The words Calcareous Stone, Granite, Spar, Schorle, Feld Spar, Schistus, Mica, &c. alone compose the dictionary of several amateurs of natural history; but the disposition of these substances in the bowels of the earth, their respective position in the composition of the globe, their formation and successive decompositions, their uses in the arts, and the knowledge of their constituent principles, form a science which can be well known and investigated by the chemist only.

It is necessary therefore that mineralogy ſhould be enlightened by the ſtudy of chemiſtry; and we may obſerve that, ſince theſe two ſciences have been united, the labour of working mines has been ſimplified, metallic ores have been wrought with more intelligence, ſeveral new metallic ſubſtances have been diſcovered, individuals have opened mines in the provinces; and we have become familiar with a ſpecies of induſtry which ſeemed foreign, and almoſt incompatible with, our ſoil and our habits. Steel and the other metals have received in our manufactories that degree of perfection which had till lately excited our admiration, and humiliated our ſelf-love. The ſuperb manufacture of Creuſot has no equal in Europe. Moſt of our works are ſupported by pit-coal; and this new combuſtible ſubſtance is ſo much the more valuable, as it affords us time to repair our exhauſted woods, and as it is found almoſt every where in thoſe barren ſoils which repel the ploughſhare, and prohibit every other kind of induſtry. The eternal gratitude of this country is therefore due to Meſſrs. Jars, Dietrich, Duhamel, Monet, Genſanne,

Genſanne, &c. who firſt brought us acquainted with theſe true riches. The taſte for mineralogy, which has diffuſed itſelf within our remembrance, has not a little contributed to produce this revolution; and it is in a great meaſure owing to thoſe collections of natural hiſtory, againſt which ſome perſons have ſo much exclaimed, that we are indebted for this general taſte. Our collections have the ſame relation to natural hiſtory, as books bear to literature and the ſciences. The collection frequently is nothing more than an object of luxury to the proprietor; but in this very caſe it is a reſource always open to the man who is deſirous of beholding, and inſtructing himſelf. It is an exemplar of the works of nature, which may be conſulted every moment; and the chemiſt who runs over all theſe productions, and ſubjects them to analyſes to aſcertain their conſtituent principles, forms the precious chain which unites nature and art.

3. While the chemiſt attends to the nature of bodies, and endeavours to aſcertain their conſtituent principles, the natural philoſopher

philofopher ftudies their external characters, and as it were their phyfiognomy. The object of the chemift ought therefore to be united to that of the philofopher, in order to acquire a complete idea of a body. What in fact fhall we call Air or Fire, without the inftruction of the chemift? Fluids more or lefs compreffible, ponderous, and elaftic. What are the particulars of information which natural philofophy affords us concerning the nature of folids? It teaches us to diftinguifh them from each other, to calculate their weight, to determine their figure, to afcertain their ufes, &c.

If we caft our attention upon the numerous particulars which chemiftry has lately taught us refpecting air, water, and fire, we fhall perceive how much the connection of thefe two fciences has been ftrengthened. Before this revolution, natural philofophy was reduced to the fimple difplay of machines; and this coquetry, by giving it a tranfient glare, would have impeded its progrefs, if chemiftry had not reftored it to its true deftination. The celebrated chancellor

chancellor Bacon compared the natural magic, or experimental philoſophy, of his time, to a magazine in which a few rich and valuable moveables were found among a heap of toys. The curious, ſays he, is exhibited inſtead of the uſeful. What more is required to draw the attention of great men, and to form that tranſient faſhion of the day which ends in contempt?

The natural philoſophy of our days no longer deſerves the reproaches of this celebrated philoſopher. It is a ſcience founded on two baſes equally ſolid. On the one part, it depends on mathematical ſcience for its principles; and, on the other, it reſts upon chemiſtry. The natural philoſopher will attend equally to both ſciences.

The ſtudy of chemiſtry, in certain departments, is ſo intimately connected with that of natural philoſophy, that they are inſeparable; as, for example, in reſearches concerning air, water, fire, &c. Theſe ſciences very advantageouſly aſſiſt each other in other reſpects; and while the chemiſt clears minerals from the foreign

bodies

bodies which are combined with them, the philofopher fupplies the mechanical apparatus neceffary for exploring them. Chemiftry is infeparable from natural philofophy, even in fuch parts as appear the moft independent of it; fuch, for example, as optics, where the natural philofopher can make no progrefs but in proportion as the chemift fhall bring his glafs to perfection.

The connection between thefe two fciences is fo intimate, that it is difficult to draw a line of diftinction between them. If we confine natural philofophy to enquiries relative to the external properties of bodies, we fhall afford no other object but the mere outfide of things. If we reftrain the chemift to the mere analyfis, he will at moft arrive at the knowledge of the conftituent principles of bodies, and will be ignorant of their functions. Thefe diftinctions in a fcience which has but one common purpofe, namely the complete knowledge of bodies, cannot longer exift; and it appears to me that we ought abfolutely to reject them in all objects which can only be be well examined by the union of natural philosophy and chemistry.

At the period of the revival of letters, it was of advantage to separate the learned, as it were, upon the road to truth; and to multiply the workshops, if I may use the expression, to hasten the clearing away. But at present, when the various points are re-united, and the connection between the whole is seen, these separations, these divisions, ought to be effaced; and we may flatter ourselves that, by uniting our efforts, we may make a rapid progress in the study of nature. The meteors, and all the phenomena of which the atmosphere is the grand theatre, can be known only by this re-union. The decomposition of water in the bowels of the earth, and its formation in the fluid which surrounds us, cannot but give rise to the most happy and the most sublime applications.

4. The connection between chemistry and pharmacy is so intimate, that these two sciences have long been considered as one and the same; and chemistry, for a long time, was cultivated only by physicians and apothe-

apothecaries. It must be allowed that, though the chemistry of the present day is very different from pharmacy, which is only an application of the general principles of this science, these applications are so numerous, the class of persons who cultivate pharmacy is in general so well informed, that it is not at all to be wondered at, that most apothecaries should endeavour to enlighten their profession by a serious study of chemistry, and by the happiest agreement unite the knowledge of both parts of science.

The abuses which, at the beginning of the present century, were made of the applications of chemistry to medicine, have caused the natural and intimate relations of this science with the art of healing to be mistaken. It would have been more prudent, no doubt, to have rectified its applications; but unfortunately we have too much ground to reproach physicians for going to extremes. They have, without restriction, banished that which they before received without examination; and we have seen them successively deprive their

their art of all the aſſiſtance it might obtain from the auxiliary ſciences.

In order to direct with propriety the applications of chemiſtry to the human body, proper views muſt be adopted relating to the animal economy, together with accurate notions of chemiſtry itſelf. The reſults of the laboratory muſt be conſidered as ſubordinate to phyſiological obſervations. We ſhould endeavour to enlighten the one by the other, and to admit no truth as eſtabliſhed which is contradicted by any of theſe means of conviction. It is in conſequence of a departure from theſe principles that the human body has been conſidered as a lifeleſs and paſſive ſubſtance; and that the ſtrict principles obſerved in the operations of the laboratory have been applied to this living ſyſtem.

In the mineral kingdom, every thing is ſubjected to the invariable laws of the affinities. No internal principle modifies the action of natural agents; and hence it ariſes that we are capable of foretelling, producing, or modifying the effects.

In the vegetable kingdom, the action of external

external agents is equally evident; but the internal organization modifies their effects, and the principal functions of vegetables arise from the combined action of external and internal causes. It was no doubt for this reason that the Creator disposed the principal organs of vegetation upon the surface of the plant, in order that the various functions might at the same time receive the impressions of external agents, and that of the internal principle of the organization.

In animals, the functions are much less dependant on external causes; and nature has concealed the principal organs in the internal part of their bodies, as if to withdraw them from the influence of foreign powers. But the more the functions of an individual are connected with its organization, the less is the empire of chemistry over them; and it becomes us to be cautious in the application of this science to all the phenomena which depend essentially upon the principles of life.

We must not however consider chemistry as foreign to the study and practice of

medicine.

medicine. This fcience alone can teach us the difficulty and art of combining remedies. This alone can teach us to apply them with prudence and firmnefs. Without the affiftance of this fcience, the practitioner would fcarcely venture to apply thofe powerful remedies from which the chemical phyfician knows the means of deriving fuch great advantage. Chemiftry alone, in all probability, is capable of affording means of combating epidemic diforders, which in moft cafes are caufed by an alteration in the air, the water, or our food. It will be only in confequence of analyfis that the true remedy can be found againft thofe ftony concretions which form the matter of the gout, the ftone, the rheumatifm, &c.; and the valuable particulars of information which we now poffefs refpecting refpiration, and the nature of the principal humours of the human body, are likewife among the benefits arifing from this fcience.

5. Chemiftry is not only of advantage to agriculture, phyfic, mineralogy, and medicine, but its phenomena are interefting to all

all the orders of men: the applications of this science are so numerous, that there are few circumstances of life in which the chemist does not enjoy the pleasure of seeing its principles exemplified. Most of those facts which habit has led us to view with indifference, are interesting phenomena in the eyes of the chemist. Every thing instructs and amuses him; nothing is indifferent to him, because nothing is foreign to his pursuits; and nature, no less beautiful in her most minute details than sublime in the disposition of her general laws, appears to display the whole of her magnificence only to the eyes of the chemical philosopher.

We might easily form an idea of this science, if it were possible to exhibit in this place even a sketch of its principal applications. We should see, for example, that chemistry affords us all the metals of which the uses are so extensive; that chemistry affords us the means of employing the parts of animals and of plants for our ornament; that our luxuries, and our subsistence, are by this science established as a tax upon all

created

created beings; and that by this power we are taught to ſubject nature to our wants, our taſte, and even to our caprices. Fire, that free independent element, has been collected and governed by the induſtry of the chemiſt; and this agent, deſtined to penetrate, to enliven, and to animate the whole of nature, has in his hands become the agent of death, and the prime miniſter of deſtruction. The chemiſts who in our time have taught us to inſulate that pure air which alone is proper for combuſtion, have placed in our hands, as it were, the very eſſence of fire; and this element, whoſe effects were ſo terrible, becomes the agent of ſtill more terrible conſequences. The atmoſphere, which was formerly conſidered as a maſs of homogeneous fluid, is now found to be a true chaos, from which analyſis has obtained principles ſo much the more intereſting to be known, as nature has made them the principal agents of her operations. We may conſider this maſs of fluid in which we live as a vaſt laboratory, in which the meteors are prepared, in which all the ſeeds of life and

of

of death are developed, from which nature takes the elements of the compofition of bodies, and to which their fubfequent decompofition returns the fame principles which were before extracted.

Chemiftry, by informing us of the nature and principles of bodies, inftructs us perfectly concerning our relation to the objects around us. This fcience teaches us, as it were, to live with them; and impreffes a true life upon them, fince by this means each body has its name, its character, its ufes, and its influence, in the harmony and arrangement of this univerfe.

The chemift, in the midft of thofe numerous beings which the common race of men accufe nature of having vainly placed upon our globe, enjoys the profpect as it were in the centre of a fociety, all whofe members are connected together by intimate relations, and concur to promote the general good. In his fight, every thing is animated, every being performs a part on this vaft theatre; and the chemift who participates in thefe interefting fcenes, is repaid with ufury for his firft exertions

to

to discover the relations existing between them.

We may even consider this commerce, or mutual relation between the chemist and nature, as very proper to soften the manners, and to impress on the character that freedom and firmness of principle so valuable in society. In the study of natural history, no cause ever presents itself to complain of inconstancy or treachery. An attachment is easily contracted for objects which afford enjoyment only; and these connections are as pure as their object, as durable as nature, and stronger in proportion to the exertions which have been required to establish them.

From all these considerations, there is no science which more eminently deserves to enter into the plan of a good education than chemistry. We may even affirm that the study of this science is almost indispensably necessary to prevent us from being strangers in the midst of the beings and phenomena which surround us. It is true indeed that the habit of beholding the objects of nature may produce a knowledge of some of their principal properties. We may even in this way arrive at the theory of some of the phenomena. But nothing is more proper to check the pretensions of young persons who are elevated by such imperfect acquisitions, than to shew them the vast field of which they are ignorant. The profound sentiment of their ignorance will be seconded by the natural desire of acquiring new knowledge. The wonderful properties of the objects presented to them will engage their attention. The interesting nature of the phenomena will tend to excite their curiosity. Accuracy of experiment, and strictness of result, will form their reasoning powers, and render them severe in their judgment. By studying the properties of all the bodies which surround him, the young scholar learns to know their relation with himself; and by successively attending to all objects, he extends the circle of his enjoyment by new conquests. He becomes a partaker in the privileges of the Creator, by uniting and disuniting, by compounding and destroying. We might even affirm that the

Author

Author of nature, reſerving to himſelf alone the knowledge of his general laws, has placed man between himſelf and matter, that it may receive theſe laws from his hands, and that he may apply them with proper modifications and reſtrictions. In this view, therefore, we may conſider man as greatly ſuperior to the other beings which compoſe this living ſyſtem. They all follow a monotonous and invariable proceſs; receive the laws, and ſubmit to effects without modification. Man alone poſſeſſes the rare advantage of knowing a part of theſe laws, of preparing events, of predicting reſults, of producing effects at pleaſure, of removing whatever is noxious, of appropriating whatever is beneficial, of compoſing ſubſtances which nature herſelf never forms; and, in this laſt point of view, himſelf a Creator, he appears to partake with the Supreme Being in the moſt eminent of his prerogatives.

ELEMENTS

OF

CHEMISTRY.

PART THE FIRST.

CONCERNING THE CHEMICAL PRINCIPLES;

INTRODUCTION.

Definition of Chemiſtry; its Object and Means.—Deſcription of a Laboratory, and the principal Inſtruments employed in chemical Operations, with a Definition of thoſe Operations.

CHEMISTRY is a ſcience, the object of which is to aſcertain the nature and properties of bodies.

The methods uſed to obtain this knowledge are reducible to two; analyſis and ſyntheſis.

The principal operations of chemiſtry are performed in a place called a Laboratory.

A laboratory ought to be extenſive and well aired, in order to prevent dangerous vapours from remaining, which are produced in ſome operations, or which may eſcape by any unforeſeen accident. It ought to be dry, becauſe otherwiſe iron veſſels would ruſt, and moſt of the chemical products would be liable to change. But the principal excellence of a laboratory conſiſts in its being furniſhed with all thoſe inſtruments which may be employed in the ſtudy of the nature of bodies, and in enquiries reſpecting their properties.

Among theſe inſtruments there are ſome which are of general uſe, and applicable to moſt operations; and there are others which ſerve only for peculiar uſes. This diviſion immediately points out that, at the preſent inſtant, we can only treat of the former, and that we muſt deſcribe the others on ſuch occaſions as will render it neceſſary to treat of their uſes.

The chemical inſtruments moſt frequently employed are thoſe which preſent themſelves firſt to view upon entering a laboratory; namely, the furnaces.

Theſe furnaces conſiſt of earthen veſſels appropriated to the various operations performed upon bodies by means of fire.

A proper

A proper mixture of ſand and clay is commonly the material of which theſe veſſels are formed. It is difficult, and even impoſſible, to preſcribe and determine, according to any invariable method, the proportions of theſe conſtituent parts; becauſe they muſt be varied according to the nature of the earths made uſe of. Habit and experience alone can furniſh us with principles on this ſubject.

The ſeveral methods of applying fire to ſubſtances under examination have occaſioned the conſtruction of furnaces in different forms, which we ſhall at preſent reduce to the three following.

I. The evaporatory furnace.—This furnace has received its name from its uſe. It is uſed to reduce liquid ſubſtances into vapour by means of heat, in order to ſeparate the more fixed principles from thoſe which are more ponderous; and were mixed, ſuſpended, compounded, or diſſolved in the fluid.

The fire-place is covered by the evaporatory veſſel. Two or three grooves, channels, or depreſſions are made in the ſides of the furnace, near its upper edge, to facilitate the drawing of the fire.

The veſſel which contains the ſubſtance to be evaporated, is called the evaporatory veſſel.

Thefe veffels are formed of earth, glafs, or metal. Veffels of unglazed earth are too porous, infomuch that liquids filtrate through their texture. Thofe of porcelain bifcuit are likewife penetrable by liquids ftrongly heated, and fuffer gafeous or aëriform fubftances to efcape. The beautiful experiment of Mr. D'Arcet upon the combuftion and deftruction of the diamond, in balls of porcelain, are well known, and tend to illuftrate this fubject. I have confirmed thefe refults by experiments in the large way, upon the diftillation of aqua-fortis, which lofes as well in quality as quantity when the procefs is carried on in veffels of porcelain clay.

Glazed earthen veffels cannot be ufed when the glafs confifts of the calces of lead or copper; becaufe thofe metallic matters are attacked by acids, fats, oils, &c. Neither can earthen veffels be ufed which are covered with enamel, becaufe this kind of opake glafs is almoft always full of fmall cracks through which the liquid would introduce itfelf into the body of the veffel.

Earthen veffels cannot therefore be ufed, excepting in operations of little delicacy, in which precifion and accuracy are not indifpenfably required.

Evaporatory

Evaporatory veſſels of glaſs are in general to be preferred. Thoſe which reſiſt the fire better than any others, are prepared in the laboratory, by cutting a ſphere of glaſs or a receiver into two equal parts with a red-hot iron. The capſules which are made in the glaſs-houſe are thickeſt at the bottom, and conſequently are more liable to break at that part when expoſed to the fire.

Evaporatory veſſels of metal are uſed in manufactories. Copper is moſt commonly employed, becauſe it not only poſſeſſes the property of reſiſting fire, but has a conſiderable degree of ſolidity, together with the facility of being wrought. Alembics are made of this metal, for the diſtillation of vinous ſpirits, and aromatic ſubſtances; as are alſo caldrons or pots for cryſtallization of certain ſalts, and for ſeveral dyeing proceſſes, &c. Lead is likewiſe of conſiderable uſe, and is made choice of whenever operations are to be performed upon ſubſtances which contain the ſulphuric acid, ſuch as the ſulphates of alumine and of iron; and for the concentration and rectification of the oils of vitriol. Tin veſſels are alſo employed in ſome operations: the ſcarlet bath affords a more beautiful colour in boilers of this metal than in thoſe of any other. Capitals of

tin

tin have already begun to be subſtituted in the room of thoſe of copper, in the conſtruction of alembics; and by this means the ſeveral products of diſtillation are exempted from every ſuſpicion of that dangerous metal. Boilers of iron are likewiſe uſed for certain coarſe operations; as for example, in the concentration of the lixiviums of common ſalt, of nitre, &c.

Evaporatory veſſels of gold, of ſilver, or of platina, are to be preferred in ſome delicate operations; but the price and ſcarcity of theſe veſſels do not permit them to be uſed, eſpecially in the large way.

Moreover it is from the nature of the ſubſtance to be evaporated, that we muſt determine the choice of the veſſel moſt ſuitable to any operation. There is no particular kind of veſſels which can be adapted excluſively on all occaſions. It may only be obſerved, that glaſs preſents the greateſt number of advantages, becauſe it is compoſed of a ſubſtance the leaſt attacked, the leaſt ſoluble, and the leaſt deſtructible by chemical agents.

Evaporatory veſſels are known by the name of capſules, cucurbits, &c. according to their ſeveral forms.

Theſe veſſels ought in general to be very wide and ſhallow, in order that the diſtillation and evaporation may be ſpeedy and œconomical. It is neceſſary, 1. That the evaporatory veſſel be not narrow at its upper part. 2. That the heat be applied to the liquid in all parts, and equally. 3. That the column or maſs of the liquid ſhould have little depth, and a large ſurface of evaporation. It is upon theſe principles that I have conſtructed, in Languedoc, boilers proper for diſtilling brandy, which ſave eleven-twelfths of the time, and four-fifths of the combuſtibles.

Evaporation may be performed in three manners. 1. By a naked fire. 2. By the ſand bath. 3. By the water bath.

Evaporation is made by a naked fire, when there is no ſubſtance interpoſed between the fire and the veſſel which contains the liquid intended to be evaporated; as, for example, when water is boiled in a pot.

Evaporation is performed by the ſand bath, when a veſſel filled with ſand is interpoſed between the fire and the evaporatory veſſel. The heat is in this caſe communicated more ſlowly and gradually; and the veſſels, which would otherwiſe have been broken by the immediate application of the heat, are enabled to reſiſt its force. The heat is at the ſame time more equally kept up; the refrigeration is more gradual;

dual; and the operations are performed with a greater degree of order, precifion, and facility.

If, inftead of employing a veffel filled with fand, we ufe a veffel of water, and the evaporatory veffel be plunged in the liquid, the evaporation is faid to be made on the water bath: in this cafe, the fubftance to be evaporated is only heated by communication from the water. This form or method of evaporation is employed when certain principles of great volatility, fuch as alcohol, or the aromatic principles of plants, are to be extracted or diftilled. It poffeffes the advantage of affording products which are not changed by the fire, becaufe the heat is tranfmitted to them by the intervention of a liquid: it is this circumftance which renders the procefs valuable for the extraction of volatile oils, perfumes, ethereal liquids, &c. It poffeffes the advantage of affording a heat nearly equal, becaufe the degree of ebullition is a term nearly conftant; and this ftandard heat may be graduated or varied at pleafure, by adding falts to the liquid of the water bath, becaufe this fingle circumftance renders the ebullition more or lefs quick and eafy. The fame effect may likewife be produced by reftraining the evaporation; for in this cafe the liquid may affume a degree of heat much more confiderable, as is ſeen in the digeſter of Papin, ſteam engines, eolipiles, and the boilers for ſtriking the red tinge in cotton.

Sublimation differs from evaporation, becauſe the ſubſtance to be raiſed is ſolid. The veſſels uſed in this operation are known by the name of ſublimatory veſſels. Theſe are commonly globes terminating in a long neck: they are then called mattraſſes.

In order to ſublime any ſubſtance, a part of the ball of the mattraſs is ſurrounded with ſand. The matter which is volatilized by the heat, riſes, and is condenſed againſt the coldeſt part of the veſſel; where it forms a ſtratum or cake, that may be taken out by breaking the veſſel itſelf. In this manner it is that ſal ammoniac, corroſive ſublimate, and other ſimilar products, are formed for the purpoſes of commerce.

Sublimation is uſually performed either for the purpoſe of purifying certain ſubſtances, and diſengaging them from extraneous matters; or elſe to reduce into vapour, and combine under that form, principles which would have united with great difficulty if they had not been brought to that ſtate of extreme diviſion.

II. The reverberatory furnace.—The name of the reverberatory furnace has been given to

that

that conſtruction which is appropriated to diſtillation.

This furnace is compoſed of four parts. 1. The aſh-hole, intended for the free paſſage of the air, and to receive the aſhes or reſidue of the combuſtion. 2. The fire-place, ſeparated from the aſh-hole by the grate, and in which the combuſtible matter is contained. 3. A portion of a cylinder, which is called the laboratory, becauſe it is this part which receives the retorts employed in the operations or diſtillations. 4. Theſe three pieces are covered with a dome, or portion of a ſphere, pierced near its upper part by an aperture, which affords a free paſſage to the current of air, and forms a chimney. The moſt uſual form of the reverberatory furnace is that of a cylinder terminated by a hemiſphere, out of which ariſes a chimney of a greater or leſs length, to produce a ſuitable degree of aſpiration.

In order that a reverberatory furnace may be well proportioned, it is neceſſary, 1. That the aſh-hole ſhould be large, to admit the air freſh and unaltered. 2. That the fire-place and laboratory together ſhould have the form of a true ellipſis, whoſe two foci ſhould be occupied by the fire and the retort. In this caſe all the

the heat, whether direct or reflected, will ſtrike the retort.

The reverberatory furnace is uſed for diſtillation. Diſtillation is that proceſs by which the force of fire is applied to diſunite and ſeparate the ſeveral principles of bodies, according to the laws of their volatility, and their ſeveral affinities.

Diſtilling veſſels are known by the name of retorts.

Retorts are formed of glaſs, of ſtone-ware, of porcelain, or of metal; theſe ſubſtances being reſpectively uſed, according to the nature of the bodies intended to be expoſed to diſtillation.

Whatever be the nature of the material, the forms of retorts are the ſame. This figure reſembles an egg, terminating in a beak or tube, which diminiſhes inſenſibly in diameter, and is ſlightly inclined or bended.

The oval portion of the retort, which is called its belly, is placed in the laboratory of the furnace, and is ſupported upon two bars of iron, which ſeparate the laboratory from the fire-place; while the beak or neck of the retort iſſues out of the furnace through a circular aperture formed in the edges of the dome and of the laboratory.

A veſſel intended to receive the product of the

the diſtillation is fitted to the neck of the retort. This veſſel is called the recipient, or receiver.

The receiver is commonly a ſphere with two apertures; the one of conſiderable magnitude, to receive the neck of the retort; the other ſmaller, to afford vent for the vapours. This part is called the tubulure of the receiver; whence the terms tubulated receiver, or receiver not tubulated, &c.

Though the reverberatory furnace be particularly adapted to diſtillation, this operation may be performed on the ſand-bath; and here, as in other caſes, it depends ſingly on the intelligence of the artiſt to vary his apparatus according to the neceſſity of circumſtances, and the nature of the ſubſtances upon which he operates.

The conſtruction of theſe furnaces may likewiſe be varied; and the chemiſt will find it neceſſary to learn the art of availing himſelf of every apparatus he poſſeſſes, to carry his operations into execution: for if he ſhould perſuade himſelf that it is impoſſible to proceed in chemical reſearch, excepting in a laboratory provided with all ſuitable veſſels, he may let the moment paſs in which a diſcovery might be made, but which may not again return.

And

And it may be truly ſaid, that he who treads ſervilely in the paths of others who have gone before him, will never attain to the diſcovery of new truths.

III. The forge furnace.—The forge furnace is that in which the current of air is determined by bellows. The aſh-hole, the fire-place, and the laboratory are here all united together; and this aſſemblage forms only a portion of a cylinder, pierced near the lower angle by a ſmall hole, into which the tube of the bellows enters. This part is ſometimes covered with a hemiſphere or dome, to concentrate the heat with greater efficacy, and to reflect it upon the bodies expoſed to it. The forge furnace is employed in the fuſion and calcination of metals, and generally for all the operations which are performed in crucibles.

By crucibles we underſtand veſſels of earth or metal, which are almoſt always of the form of an inverted cone. A crucible ought to ſupport the ſtrongeſt heat without melting; it ought to reſiſt the attacks of all ſuch agents as are expoſed to heat in veſſels of this kind. Thoſe crucibles which poſſeſs the greateſt degree of perfection, are made in Heſſe or in Holland. I have made very good ones by a mixture

mixture of raw and unbaked clay from Salavas in the Vivarais.

Our laboratories have been provided with crucibles of platina, which unite the moſt excellent properties. They are nearly infuſible, and at the ſame time indeſtructible by the fire.

The ſeveral earthen veſſels concerning which we have here treated, may be fabricated by hand, or wrought in the lathe. The firſt proceeding renders them more ſolid, the clay is better united, and it is the only method uſed in glaſs manufactories; but the ſecond method is more expeditious.

The agent of ſuch decompoſitions as are effected by means of furnaces, is fire. It is afforded by the combuſtion of wood, pit-coal, or charcoal.

Wood is only employed in certain large works; and we prefer charcoal in our laboratories, becauſe it does not ſmoke, has no bad ſmell, and burns better in ſmall maſſes than other combuſtibles. We chooſe that which is the moſt ſonorous, the drieſt, and the leaſt porous.

But, in the ſeveral operations we are about to deſcribe, it is neceſſary to defend the retorts from the immediate action of the fire; and alſo to coerce and reſtrain the expanſible vapours,

vapours, which are very elaſtic, and frequently corroſive. It is to anſwer theſe purpoſes that various lutes are employed.

1. A glaſs retort expoſed to the action of the fire would infallibly break, if the operator were not to have recourſe to the prudent precaution of coating it with earth.

I have found it advantageous for the coating of retorts, to uſe a mixture of fat earth and freſh horſe dung: for this purpoſe, the fat earth is ſuffered to rot for ſome hours in water; and when it is moiſtened, and properly ſoftened, it muſt be kneaded with the horſe dung, and formed into a ſoft paſte, which is to be applied and ſpread with the hand upon every part of the retort intended to be expoſed to the action of the fire. The horſe dung combines ſeveral advantages. 1. It contains a ſerous fluid, which hardens by heat, and ſtrongly connects all the parts together: when this juice has been altered by fermentation or age, the dung does not poſſeſs the ſame virtue. 2. The filaments or ſtalks of hay, which are ſo eaſily diſtinguiſhed in horſe dung, unite all the parts of the lute together.

Retorts luted in this manner reſiſt the impreſſion of the fire very well; and the adheſion of the lute to the retort is ſuch, that even ſhould the

the retort fly during the operation, the diſtillation may be ſtill carried on, as I have daily experience in works in the large way.

2. When it is required to coerce or oppoſe the eſcape of the vapours which are diſengaged during any operation, it is no doubt ſufficient if the joinings of the veſſels be covered with paper glued on, or with ſlips of bladder moiſtened with the lute of lime and white of egg, provided the vapours be neither dangerous nor corroſive; but, when the vapours are corroſive, it is neceſſary to uſe the fat lute to retain them.

'Fat lute is made with boiled linſeed oil mixed and well incorporated with ſifted clay. Nut oil, kneaded with the ſame clay, forms a lute poſſeſſing the ſame properties. It is eaſily extended in the hand, and is uſed for defending the joinings of veſſels, upon which it is afterwards ſecured by ſtrips of linen, dipped in the lute of lime and white of egg. Before the application of heat in any diſtillation, it is neceſſary firſt to ſuffer the lutes to dry. Without this precaution, the vapours would riſe and eſcape; or otherwiſe they would combine with the water which moiſtens the lutes, and would corrode and deſtroy the bladder, the ſkin, the paper, and in a word every ſubſtance uſed to ſecure them in their places. The lute of lime and

white

white of egg dries very ſpeedily, and muſt be uſed the moment it is made. This lute, likewiſe, oppoſes the greateſt reſiſtance to the eſcape of the vapours, and adheres the moſt intimately to the glaſs. It is made by mixing a ſmall quantity of finely-powdered quick-lime with white of egg, and afterwards beating up the mixture to facilitate the combination. It muſt then be inſtantly applied on pieces of old linen, to be wrapped round the places of joining.

In the large works, where it is not poſſible to attend to all theſe minute details, the joinings of the retort and receiver are luted together with the ſame lute which is uſed to coat the retorts. A covering of the thickneſs of a few lines is ſufficient to prevent the vapours of the marine or nitrous acid from eſcaping.

As in certain operations a diſengagement takes place of ſo prodigious a quantity of vapours, that it is dangerous to confine them; and as, on the other hand, the ſuffering them to eſcape would occaſion a conſiderable loſs in the product; an apparatus has been contrived of great ingenuity and ſimplicity to moderate the iſſue, and to retain without riſk ſuch vapours as would otherwiſe eſcape. This apparatus is known by the name of its author, Mr. Woulfe, a famous Engliſh chemiſt. His moſt excellent proceſs conſiſts in adapting the extremity of a recurved tube to the tubulure of the receiver; the other end of which is plunged into water, in a bottle half filled, and properly placed for that purpoſe. From the empty part of this bottle iſſues a ſecond tube, which is in like manner plunged in the water of a ſecond bottle. A number of other bottles may be added, obſerving the ſame precautions; with the attention, nevertheleſs, to leave the laſt open, to give a free eſcape to the vapours which are not coercible: and, when the apparatus is thus diſpoſed, all the joinings are to be luted. It will eaſily be imagined that the vapours which eſcape from the retort are obliged to paſs through the tube adapted to the tubulure of the receiver, and conſequently muſt paſs through the water of the firſt bottle: they therefore ſuffer a firſt reſiſtance, which partly condenſes them. But as almoſt all vapours are more or leſs miſcible and ſoluble in water, a calculation is previouſly made of the quantity of water neceſſary to abſorb the vapours which are diſengaged from the mixture in the retort; and care is taken to diſtribute this proper quantity of water in the bottles of the apparatus.

By this means we obtain the pureſt and moſt concentrated products; becauſe the water, which

which is always the receiver, and is the vehicle of theſe ſubſtances, becomes ſaturated with them. There is, perhaps, no other method of obtaining products always of an equal energy, and comparable in their effects; a circumſtance of the greateſt importance in the operations of the arts, as well as in philoſophical experiments.

I have applied this apparatus to works in the large way; and I uſe it to extract the common muriatic acid, the oxigenated muriatic acid, ammoniac or volatile alkali, &c.

As it would very often happen, in this apparatus, that the preſſure of the external air would cauſe the water of the outer veſſels to paſs into the receiver, in conſequence of the ſimple refrigeration of the retort; this inconvenience has been obviated, by inſerting a ſtraight tube into the necks of the firſt and the ſecond bottles, to ſuch a depth, that its lower end is plunged into the water, while its other end riſes ſeveral inches above the neck of the bottle. It may eaſily be conceived, as a conſequence of this diſpoſition, that when the dilated vapours of the receiver and retort are condenſed by cooling, the external air will ruſh through theſe tubes to eſtabliſh the equilibrium; and the water cannot paſs from the one to the other.

Before the invention of this apparatus, it was usual to drill a hole in the receiver, which was kept closed, and only opened from time to time for the escape of the vapours. This method was inconvenient in many respects. In the first place, and principally, because, in spite of all precautions, it was attended with the risk of an explosion every moment, by the irregular disengagement of the vapours, and the impossibility of calculating the quantity produced in a given time. A second inconvenience was, that the vapours which thus escaped occasioned a considerable loss in the product, and even weakened the remainder; because this volatile principle consisted of the strongest part. A third inconvenience was, that the vapours which did escape incommoded the artist to such a degree, that it was impossible to perform most of the operations of chemistry in the course of a lecture, where a considerable number of auditors were present.

Thus it is that the apparatus of Woulfe unites a number of advantages: on the one hand, economy in the processes, and superiority in the product; on the other hand, safety for the chemist and his assistants: and, in every point of view, the author is entitled to the best acknowledgments of chemists, who were too often so much affected with these unwholesome exhalations,

exhalations, that their health was either totally deſtroyed, or they fell abſolute victims to their zeal for the promotion of ſcience.

It is neceſſary that a laboratory ſhould be provided with balances of the utmoſt accuracy; for the chemiſt, who very frequently operates only upon ſmall quantities, ought to be able, by the ſtrictneſs of his operations, and the accuracy of his apparatus, to produce reſults comparable with thoſe of works in the large way. It frequently happens that the ſimple eſſay of a ſpecimen of an ore determines the opening of a mine: and it ſcarcely need be pointed out, of how great conſequence it is to remove every cauſe of error from the operations of chemiſtry; ſince the ſlighteſt error in the works of the laboratory may be attended with the moſt unhappy conſequences, when the application of the principles is made to works in the large way.

We ſhall treat of other veſſels and chemical apparatus, in proportion as we ſhall have occaſion to make uſe of them; for it appears to us that, by thus connecting the deſcription with their uſe, we ſhall ſucceed better in rendering them intelligible to the reader, at the ſame time that his memory will be leſs fatigued.

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SECTION I.

Concerning the General Law which tends to bring the Particles of Bodies together, and to maintain them in a State of Mixture or Combination.

THE Supreme Being has given a force of mutual attraction to the particles of matter; a principle which is alone ſufficient to produce that arrangement which the bodies of this univerſe preſent to our obſervation. As a very natural conſequence of this primordial law, it follows that the elements of bodies muſt have been urged towards each other; that maſſes muſt have been formed by their re-union; and that ſolid and compact bodies muſt have inſenſibly been conſtituted; towards which, as towards a centre, the leſs heavy and leſs compact bodies muſt gravitate.

This law of attraction, which the chemiſts call Affinity, tends continually to bring principles together which are diſunited, and retains with more or leſs energy thoſe which are already in combination; ſo that it is impoſſible to produce any change in nature, without interrupting or modifying this attractive power.

It

It is natural, therefore, and even indiſpenſable that we ſhould ſpeak of the law of the affinities before we proceed to treat of the methods of analyſis.

Affinity is exerciſed either between principles of the ſame nature, or between principles of a different nature.

We may, therefore, diſtinguiſh two kinds of affinity, with reſpect to the nature of bodies. 1. The affinity of aggregation, or that which exiſts between two principles of the ſame nature. 2. The affinity of compoſition, or that which retains two or more principles of different natures in a ſtate of combination.

Of the Affinity of Aggregation.

Two drops of water which unite together into one, form an aggregate, of which each drop is known by the name of an integrant part.

An aggregate differs from a heap; becauſe the integrant parts of this laſt have no perceptible adheſion to each other; as, for example, a heap of barley, of ſand, &c.

An aggregate, and a heap, differ from a mixture; becauſe the conſtituent parts of this laſt are of a different nature; as, for example, in gun-powder.

The affinity of aggregation is ſtronger, the

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nearer the integrant parts approach to each other; ſo that every thing which tends to ſeparate or remove theſe integrant parts from each other, diminiſhes their affinity, and weakens their force of coheſion.

Heat produces this effect upon moſt known bodies: hence it is that melted metals have no conſiſtence. The caloric, or matter of heat, by combining with bodies, almoſt always produces an effect oppoſite to the force of attraction; and we might conſider ourſelves as authoriſed to affirm that it is a principle of repulſion, if ſound chemiſtry had not proved that it produces this effect only by its endeavour to combine with bodies, and thereby neceſſarily diminiſhing their force of aggregation, as all other chemical agents do. Beſides which, the extreme levity of caloric produces the effect that, when it is combined with any given body, it continually tends to elevate it, and to overcome that force which retains it, and precipitates it towards the earth.

The mechanical operations of pounding, of hammering, or of cutting, likewiſe diminiſh the affinity of aggregation. They remove the integrant parts to a diſtance from each other; and this new diſpoſition, by preſenting a leſs degree of adheſion, and a larger ſurface, facilitates the immediate

immediate action, and augments the energy, of chemical agents. It is for this purpofe that bodies are divided when they are to be analyfed, and that the effect of re-agents is facilitated by the action of heat.

The mechanical divifion of bodies is more difficult, the ftronger their aggregation.

Aggregates exift under different ftates; they are folid, liquid, aëriform, &c.—See Fourcroy's Chemiftry.

Of the Affinity of Compofition.

Bodies of different kinds exert a tendency or attraction upon each other, which is more or lefs ftrong; and it is by virtue of this force that all the changes of compofition or decompofition obferved among them, are effected.

The affinity of compofition exhibits invariable laws in all the phenomena it caufes. We may ftate thefe laws as general principles; to which may be referred all the effects prefented to our obfervation by the action of bodies upon each other.

I. The affinity of compofition acts only between the conftituent parts of bodies.

The general law of attraction is exerted upon the maffes; and in this refpect it differs from the law of the affinities, which does not percep-

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tibly act but on the elementary particles of bodies. Two bodies placed near each other do not unite; but, if they be divided and mixed, a combination may ariſe. We have examples of this when the muriate of ſoda, or common ſalt, is triturated with litharge; the muriate of ammoniac, or common ſal ammoniac, with lime, &c. And it may be aſſerted, that the energy of the affinity of compoſition is almoſt always proportioned to the degree of the diviſion of bodies.

II. The affinity of compoſition is in the inverſe ratio of the affinity of aggregation.

It is ſo much the more difficult to decompoſe a body, as its conſtituent principles are united or retained by a greater force. Gaſes, and eſpecially vapours, continually tend to combination, becauſe their aggregation is weak: and nature, which is conſtantly renewing the productions of this univerſe, never combines ſolid with ſolid; but, reducing every thing into the form of gas, by this means breaks the impediments of aggregation; and theſe gaſes uniting together, form ſolids in their turn.

Hence, no doubt, it ariſes, that the affinity of compoſition is ſo much the more ſtrong as bodies approach nearer to the elementary ſtate; and we ſhall obſerve, on this ſubject, that this law of nature is founded in wiſdom: for if the force

force or affinity of compofition did not increafe in proportion as bodies were brought to this degree of fimplicity; if bodies did not affume a decided tendency to unite and combine, in proportion as they approach to their primitive or elementary ftate; the mafs of elements would continually increafe by thefe fucceffive and uninterrupted decompofitions; and we fhould infenfibly return again to that chaos or confufion of principles, which is fuppofed to have been the original ftate of this globe.

The neceffity of this ftate of divifion, which is fo proper to increafe the force of affinity, has caufed it to be admitted as an inconteftable principle, that the affinity of compofition does not take place, unlefs one of the bodies be in the fluid ftate: *corpora non agunt nifi fint fluida.* But it feems to me that extreme divifion might be fubftituted inftead of diffolution; for both thefe operations tend only to attenuate bodies, without altering their nature. It is by virtue of this divifion, which is equivalent to diffolution, that the decompofition of muriate of foda is effected by trituration with minium, as well as the union of cold and dry alkali with antimony, and the difengagement of volatile alkali by the fimple mixture of fal ammoniac with lime.

III. When two or more bodies unite by the

the affinity of compoſition, their temperature changes.

This phenomenon cannot be explained but by conſidering the fluid of heat as a conſtituent principle of bodies, unequally diſtributed amongſt them; ſo that, when any change is produced in bodies, this fluid is diſplaced in its turn, which neceſſarily produces a change of temperature. We ſhall return to thoſe principles when we ſpeak of heat.

IV. The compound which reſults from the combination of two bodies, poſſeſſes properties totally different from thoſe of its conſtituent principles.

Some chemiſts have affirmed, that the properties of compounds were intermediate between thoſe of their conſtituent parts. But this term " intermediate'' has no meaning in the preſent caſe; for what intermediate qualities can exiſt between ſour and ſweet, or between water and fire?

If we attend ever ſo little to the phenomena which are exhibited to us by bodies in their compoſition, we ſhall perceive that their form, their taſte, and their conſiſtence, are changed in combination; and we cannot eſtabliſh any rule to indicate, *a priori*, all the changes which may ariſe, and the nature and properties of the body which ſhall be formed.

V. Every

V. Every individual ſubſtance has its peculiar affinities with the various ſubſtances preſented to it.

If all bodies had the ſame degree of affinity with each other, no change could take place amongſt them: we ſhould not be able to diſplace any principle by preſenting one body to another. Nature has therefore wiſely varied the affinities, and appointed to each body its relation with all thoſe that can be preſented to it.

It is in conſequence of this difference in the affinities that all chemical decompoſitions are effected: all the operations of nature and art are founded upon it. It is therefore of importance to be well acquainted with all the phenomena and circumſtances which this law of decompoſition can preſent to us.

The affinity of compoſition has received different names, according to its effects. It is divided into ſimple affinity, double affinity, the affinity of an intermedium, reciprocal affinity, &c.

1. Two principles united together, and ſeparated by means of a third, afford an example of ſimple affinity: it conſiſts in the diplacing of one principle by the addition of a third. Bergman has given it the name of Elective Attraction.

The body which is diſengaged, or diſplaced, is is known by the name of the Precipitate. An alkali precipitates metals from their folutions; the fulphuric acid precipitates the muriatic, the nitric, &c.

The precipitate is not always formed by the difengaged fubftance. Sometimes the new compound itfelf is precipitated; as, for example, when I pour the fulphuric or vitriolic acid on a folution of muriate of lime. Sometimes the difengaged body and the new compound are precipitated together; as, for example, when the fulphate of magnefia or Epfom falt is diffolved in water, and precipitated by means of lime-water.

2. It often happens that the compound of two principles cannot be deftroyed either by a third or a fourth body feparately applied; but if thefe two bodies be united, and placed in contact with the fame compound, a decompofition or change of principles will then take place. This phenomenon conftitutes the double affinity. An example will render this propofition more clear and precife. The fulphate of pot-afh or vitriolated tartar is not completely decompofed by the nitric acid or by lime, when either of thefe principles is feparately prefented; but, if the nitric acid be combined with lime, this nitrate of lime will decompofe the fulphate of

pot-afh.

pot-ash. In this last case the affinity of the sulphuric acid with the alkali is weakened by its affinity to the lime. This acid, therefore, is subject to two attractions; the one which retains it to the alkali, and the other which attracts it towards the lime: Mr. Kirwan has named the first the Quiescent Affinity, the other the Divellent Affinity. The same may be said respecting the affinities of the alkali; it is retained to the sulphuric acid by a superior force, but nevertheless attracted by the nitric acid. Let us suppose, now, that the sulphuric acid adheres to the alkali with a force as 8, and to the lime by a force expressed by the number 6; that the nitric acid adheres to the lime by a force as 4, and tends to unite with the alkali by a force as 7. It may then be perceived that the nitric acid and the lime, separately applied to the sulphate of pot-ash, would not produce any change: but if they be presented in a state of combination, then the sulphuric acid is attracted on the one hand by 6, and retained by 8; it has therefore an effective attraction to the alkali as 2. On the other hand, the nitric acid is attracted by a force as 7, and retained by a force as 4; it therefore retains a tendency to unite with the alkali, which is denoted by the number 3; and consequently it ought to displace the sulphuric

phuric acid, which is retained only by a force as 2.

3. There are cafes in which two bodies, having no perceptible affinity to each other, obtain a difpofition to unite by the intervention of a third; and this is called the affinity of an intermedium. An alkali is the intermedium of union between oil and water; hence the theory of lixiviums, of wafhing, &c. &c.

If the affinities of bodies were well known, we might foretel the refults of all operations: but it is obvious how difficult it muft be to acquire this extenfive knowledge of nature; more efpecially fince modern difcoveries have exhibited to us an infinity of modifications in our proceffes, and have fhewn that refults may vary with fuch facility, that even the abfence or prefence of light will render them very different.

As long as chemiftry was confined to the knowledge of a few fubftances, and was bufied only in attending to a certain number of facts, it was poffible to draw up tables of affinity, and to exhibit the refult of our knowledge in one and the fame table. But all the principles upon which thefe tables have been conftructed, have received modifications; the number of principles has increafed; and we find ourfelves under the neceffity of labouring upon new ground.

ground. A fketch of this great work may be feen in the Effay on Affinities of the celebrated Bergman, and in the article Affinity in the *Encyclopédie Methodique.*

VI. The particles which are brought together and united by affinity, whether they be of the fame nature or of different natures, continually tend to form bodies of a polyhedral, conftant, and determinate form.

This beautiful law of nature, by which fhe impreffes on all her productions a conftant and regular form, appears to have been unknown to the ancients: and when chemifts began to difcover that almoft all bodies of the mineral kingdom affected regular forms, they at firft diftinguifhed them according to the inaccurate refemblance fuppofed to exift between them and other known bodies. Hence the denomination of cryftals in pyramids, needles, points of diamonds, croffes, fword blades, &c.

We are more particularly indebted to the celebrated Linnæus for the firft precife ideas of thefe geometrical figures. He took notice of the conftancy and uniformity of this character; and this celebrated naturalift thought himfelf authorifed to make it the bafis of his method of claffification of the mineral kingdom.

Mr. Romé de Lifle has proceeded ftill far-

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ther: he has ſubjected all the forms to a ſtrict examination; he has, as it were, decompoſed them; and is of opinion that he can diſtinguiſh in the cryſtals of all analogous or identical ſubſtances, the ſimple modifications and ſhades of a primitive form. By this means he has reduced all the confuſed and irregular forms to certain primitive figures; and has attributed to nature a plan or primitive deſign, which ſhe varies and modifies in a thouſand manners, according to circumſtances that influence her proceedings. This truly great and philoſophical work has rendered this part of mineralogy in the higheſt degree intereſting; and if we ſhould admit that Mr. De Liſle has perhaps carried theſe reſemblances too far, we cannot but allow that he deſerves a diſtinguiſhed place amongſt thoſe authors who have contributed to the progreſs of ſcience. The Cryſtallographie of this celebrated naturaliſt may be peruſed with advantage.

The abbé Hauy has ſince applied calculation to obſervation. He has undertaken to prove that each cryſtal has a nucleus or primitive form; and has ſhewn the laws of diminution to which the component laminæ of the cryſtals are ſubject, in their tranſition from the primitive to the ſecondary forms. The development of theſe fine principles, and their application to cryſtals the beſt known, may be ſeen in his theory of the ſtructure of cryſtals, and in ſeveral of his memoirs printed in the volumes of the Academy of Sciences.

The united labours of theſe celebrated naturaliſts have carried cryſtallography to a degree of perfection of which it did not appear ſuſceptible. But we ſhall, at this moment, attend only to the principles according to which cryſtallization is effected.

To diſpoſe a ſubſtance to cryſtallization, it is neceſſary in the firſt place to reduce it to the moſt complete ſtate of diviſion.

This diviſion may be effected by ſolution, or by an operation purely mechanical.

Solution may be effected either by the means of water or of fire. The ſolution of ſalts is in general performed in the firſt liquid, that of metals is effected by means of the ſecond; and their ſolution is not complete until a degree of heat is applied of ſufficient intenſity to convert them into the ſtate of gas.

When the water which holds any ſalt in ſolution is evaporated, the principles of the diſſolved body are inſenſibly brought nearer to each other, and it is obtained in a regular form. The ſame circumſtance nearly takes place in the ſolution by fire. When a metal is impregnated with this fluid, it does not cryſtallize but in proportion as this exceſs of igneous fluid is withdrawn.

In order that the form of a cryſtal may be regular, three circumſtances are required; time, a ſufficient ſpace, and repoſe. Conſult Linnæus, Daubenton, &c.

A. Time cauſes the ſuperabundant fluid to be ſlowly diſſipated, and brings the integral parts nearer to each other by inſenſible gradation, and without any ſudden ſhock. Theſe integrant parts therefore unite according to their conſtant laws, and form a regular cryſtal. For this reaſon it is, that ſlow evaporation is recommended by all good chemiſts. Vide Stahl's Treatiſe on Salts, chap. 29.

In proportion as the evaporation of the ſolvent is effected, the principles of the diſſolved body approach each other, and their affinity is continually augmented while that of the ſolvent remains unaltered. Hence it ariſes, no doubt, that the laſt portions of the ſolvent are moſt difficultly volatilized, and that ſalts retain a greater or leſs quantity, which forms their water of cryſtallization. The proportion of water of cryſtallization not only varies greatly in the different ſalts, but it adheres with greater

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or leſs ſtrength. There are ſome which ſuffer this water to fly off when they are expoſed to the air; ſuch as ſoda or the mineral alkali, the ſulphate of ſoda or Glauber's ſalt, &c. In this ſituation theſe ſalts loſe their tranſparency, and fall into powder: they are then ſaid to have effloreſced. There are other ſalts which obſtinately retain their water of cryſtallization; ſuch as the muriate of pot-aſh, the nitrate of pot-aſh or common nitre, &c.

The phenomena preſented to us by the different ſalts, when forcibly deprived of their water of cryſtallization, exhibit other varieties. Some crackle with the heat, and are thrown about in ſmall pieces when the water is diſſipated: this appearance is called decrepitation. Others emit the ſame water in the form of ſteam, and are liquefied with a diminution of their bulk. Others again ſwell up, and become converted into a bliſtered or porous ſubſtance.

We are indebted to Mr. Kirwan for an accurate table of the water of cryſtallization contained in each ſalt. This table may be ſeen by conſulting his Mineralogy.

The ſimple cooling of the fluid which holds the ſalt in ſolution may precipitate a conſiderable quantity. The caloric and the water diſſolve a greater quantity of ſalt when their action

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is united; and it may eaſily be imagined that the ſubtraction of one of the ſolvents muſt occaſion the precipitation of that portion which it held in ſolution. Thus it is that warm water ſaturated with ſalt muſt ſuffer a part to precipitate by cooling; and for this reaſon cryſtallization always begins at the ſurface of the liquid, and on the ſides of the containing veſſel; namely, becauſe theſe parts are the firſt which ſuffer refrigeration.

It is the alternation of heat and cold which cauſes the atmoſphere to diſſolve ſometimes a greater, and ſometimes a leſs quantity of water; and conſtitutes miſts, the evening dew, &c.

The mutual approach of the conſtituent parts of a body held in ſolution may be likewiſe accelerated by preſenting to the water which ſuſpends them, another body which has a ſtrong affinity to it. It is upon this principle that alcohol precipitates ſeveral ſalts.

B. Space or ſufficient room is likewiſe a condition neceſſary for obtaining regular cryſtallization. If nature be reſtrained in her operations, the product of her labour will exhibit ſymptoms of this ſtate of conſtraint. It may be aſſerted that nature forms her productions according to all the circumſtances which may influence her operations.

C. A ſtate

C. A ſtate of repoſe in the fluid is likewiſe neceſſary to obtain very regular forms. Uninterrupted agitation oppoſes all ſymmetrical arrangement; and in this caſe the cryſtallization obtained will be confuſed and indeterminate.

I am perſuaded that, in order to obtain bodies under the form of cryſtals, a previous ſolution is not neceſſary, but that a ſimple mechanical diviſion would be ſufficient. To obtain a conviction of this truth, it is only neceſſary to obſerve that ſolution does not change the nature of bodies, but ſimply procures an extreme ſtate of diviſion; ſo that the diſunited principles approaching each other very gradually and without ſtarts, can adapt themſelves to each other, by following the invariable laws of their gravity and affinity. Now a diviſion purely mechanical produces the ſame effect, and places the principles in the ſame diſpoſition. We ought not therefore to be ſurpriſed if moſt ſalts, ſuch as gypſum, when diſperſed in the earth, ſhould aſſume regular forms without any previous ſolution; neither ought we to think it ſtrange if the imperceptible fragments of quartz, of ſpar, &c. when carried along and prodigiouſly divided by the action of waters, ſhould be depoſited in the form of regular cryſtals.

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A very ſingular property may be obſerved in ſalts; which may be referred to cryſtallization, but is likewiſe in ſome meaſure remote from it, becauſe it does not depend upon the ſame cauſes. This is the property of riſing along the ſides of the veſſels which contain the ſolution. It is known by the name of Saline Vegetation.

I have firſt demonſtrated that this phenomenon depends on the concurrence of air and light; and that the effect may be determined at pleaſure towards any part of the veſſel, by managing and directing the action of theſe two agents.

I have ſhewn the principal forms which this ſingular vegetation affects. The detail of my experiments may be ſeen in the third volume of the Memoirs of the Academy of Toulouſe.

Mr. Dorthes has confirmed my reſults; and has moreover obſerved that camphor, ſpirits of wine, water, &c. which riſe by inſenſible evaporation in half-filled veſſels, conſtantly attach themſelves to the moſt enlightened parts of the veſſels.

Meſſrs. Petit and Rouelle have treated on the vegetation of ſalts; but a ſeries of experiments on the ſubject was wanting. This is what we have endeavoured to ſupply.

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SECTION II.

Concerning the various Means employed by Chemiſts to overcome the Adheſion which exiſts between the Particles of Bodies.

THE law of affinities, towards which our attention has been directed, tends continually to bring the particles of bodies into contact, and to maintain them in their ſtate of union. The efforts of the chemiſt are almoſt all directed to overcome this attractive power, and the means he employs are reducible to— 1. The diviſion of bodies by mechanical operations. 2. The diviſion or ſeparation of the particles from each other by the aſſiſtance of ſolvents. 3. The means of preſenting to the ſeveral principles of the ſame bodies, ſubſtances which have a ſtronger affinity to them than thoſe principles have to each other.

I. The different operations performed upon bodies by the chemiſt, to determine their nature, alter their form, their texture, and even in ſome

ſome inſtances change their conſtitution. All theſe changes are either mechanical or chemical.

The mechanical operations we ſhall at preſent deſcribe do not change the nature of ſubſtances, but in general change only their form and bulk. Theſe operations are performed by the hammer, the knife, the peſtle, &c. Whence it follows, that the chemical laboratory ought to be provided with all theſe inſtruments.

Theſe diviſions or triturations are performed in mortars of ſtone, of glaſs, or of metal. It is the nature of the ſubſtance under examination which determines the uſe of one or the other of theſe veſſels.

The object of theſe preliminary operations is, to prepare and diſpoſe bodies for new operations which may diſunite their principles and change their nature; theſe laſt-mentioned operations, which may be diſtinguiſhed by the appellation Chemical, are what moſt eſſentially conſtitute the analyſis.

II. The ſolution to which we are at preſent to attend, conſiſts in the diviſion and diſappearance of a ſolid in a liquid, but without any alteration in the nature of the body ſo diſſolved.

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The liquid in which the ſolid diſappears, is called the ſolvent or menſtruum.

The agent of ſolution appears to follow certain conſtant laws, which we ſhall here point out.

A. The agent of ſolution does not appear to differ from that of affinity; and in all caſes the ſolution is more or leſs abundant, the greater the affinity of the integrant parts of the ſolvent is to thoſe of the body to be diſſolved.

From this principle it follows, that, to facilitate ſolution, it is neceſſary that bodies ſhould be triturated and divided. By this means a greater number of ſurfaces are preſented, and the affinity of the integrant parts is diminiſhed.

It ſometimes happens that the affinity between the ſolvent and the body preſented to it has ſo little energy, that it does not become perceptible till after a conſiderable interval of time. Theſe ſlow operations, of which we have ſome examples in our laboratories, are common in the works of nature; and it is probably to ſimilar cauſes that we ought to refer moſt of thoſe reſults whoſe cauſes or agents eſcape our perception or obſervation.

B. Solution is more ſpeedy in proportion as the body to be diſſolved preſents a greater ſurface: on this principle is founded the practice

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of pounding, triturating, and dividing bodies intended to be diſſolved. Bergman has even obſerved, that bodies which are not attacked in conſiderable maſſes, become ſoluble after minute diviſion. Letters on Iceland, p. 421*.

C. The ſolution of a body conſtantly produces cold. Advantage has even been taken of this phenomenon to procure artificial cold, much ſuperior to the moſt rigorous temperature ever obſerved in our climates. We ſhall again advert to this principle when we come to treat of the laws of heat.

The principal ſolvents employed in our operations are water, alcohol, and fire. Bodies ſubmitted to one or the other of theſe ſolvents preſent ſimilar phenomena; they are divided, rarefied, and at laſt diſappear: the moſt refractory metal melts, is diſſipated in vapour, and paſſes to the ſtate of gas, if a very ſtrong heat be applied to it. This laſt ſtate forms a complete ſolution of the metallic ſubſtance in the caloric.

The effect of caloric is often united with one of the other ſolvents, to accompliſh a more ſpeedy and abundant ſolution.

The three ſolvents here mentioned do not

* Von Troil's Letters, quoted by Bergman. T.

exercife an equal action on all bodies indifcriminately. Skilful chemifts have exhibited tables of the diffolving power of thefe menftrums. We may fee, in the Mineralogy of Kirwan, with what care that celebrated chemift has exhibited the degree of folubility of each falt in water. The table of Mr. De Morveau may likewife be confulted on the diffolving power of alcohol. Journal de Phyfique, 1785.

Moft authors who have treated of folution have confidered it in too mechanical a point of view. Some have fuppofed fheaths in the folvent, and points in the body diffolved. This abfurd and gratuitous fuppofition has appeared fufficient to account for the action of acids upon bodies. Newton and Gaffendi have admitted pores in water, in which falts might infinuate themfelves; and have by this means explained why water does not augment in its bulk in proportion to the quantity of falt it takes up. Gaffendi has even fuppofed pores of different forms; and has endeavoured to fhew by this means how water faturated with one falt may diffolve others of another kind. Dr. Watfon, who has obferved the phenomena of folution with the greateft care, has concluded from his numerous experiments; 1. That the water rifes in the veffel at the moment of the immerfion

fion of the falt. 2. That it falls during the folution. 3. That it rifes after the folution above the original level. The two laft effects feem to me to arife from the change of temperature which the liquor undergoes. The refrigeration arifing from the folution muft diminifh the volume of the folvent; but it ought to return to its firft ftate as foon as the diffolution is finifhed. The tables of Dr. Watfon refpecting thefe phenomena, and the fpecific gravity of water faturated with different falts, may be confulted in the Journal de Phyfique, vol. xiii. p. 62*.

III. As the peculiar affinities of bodies to each other are various, the conftituent principles may be eafily difengaged by other fubftances; and it is upon this confideration that the action of all the re-agents employed by chemiftry in its analyfis is founded. Sometimes the chemift difplaces certain principles, which he can in that ftate examine more accurately, becaufe infulated, and difengaged from all their combinations. It frequently happens that the re-agent made ufe of combines with fome principle of the body analyfed; and a compound arifes, whofe characters indicate

* Or in the fifth vol. of his Chemical Effays. T.

to us the nature of the principle which has thus entered into combination, becaufe the combinations of the principal re-agents with various bafes are well known. It likewife frequently happens that the re-agent made ufe of is itfelf decompofed, which circumftance renders the phenomena and the products more complicated; but we are enabled from the nature of thefe products to form a judgment of the component parts of the body analyfed. This laft fact was little attended to by the ancient chemifts; and this is one of the principal defects of the labours of Stahl, who has referred moft of thofe phenomena to the bodies which he fubmitted to analyfis, which in reality arofe only from the decompofition of the re-agents employed in his operations.

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SECTION III.

Concerning the Method of Proceeding which the Chemiſt ought to follow in the Study of the various Bodies preſented to us by Nature.

THE progreſs made in any ſcience depends upon the ſolidity of thoſe principles which form its baſis, and upon the method of ſtudying them. It is not, therefore, to be wondered at, that chemiſtry made but little progreſs in thoſe times, when the language of chemiſts was enigmatical, and when the principles of the ſcience were founded only on analogies falſely deduced, or on a few facts ill underſtood. In the times which have followed this epocha, the facts have indeed been more attended to; but, inſtead of ſuffering them to ſpeak for themſelves, chemiſts have been deſirous of making applications, drawing conſequences, and eſtabliſhing theories. Thus it was that Stahl, when he firſt obſerved that oil of vitriol and charcoal produced ſulphur, if if he had then confined himſelf to the ſimple relation of the fact, would have announced a valuable and eternal truth; but when he concluded that the ſulphur was produced by the combination of the inflammable principle of the charcoal with the oil of vitriol, he aſſerted that which the experiment does not point out: then it was that he proceeded further than the facts warranted; and this firſt ráſh ſtep might be a firſt ſtep towards error. All doctrine, in order to be laſting, ought to conſiſt of the pure and ſimple expreſſion of facts: but we are almoſt always governed by our imaginations; we adapt the facts to our manner of ſeeing them, and thus we are miſled by ourſelves. The prejudice of ſelf-love afterwards furniſhes us with various means to avoid recantation; we exert ourſelves to draw our ſucceſſors into the ſame paths of error; and it is not till after much time has been loſt, after many vain conjectures have been exhibited, and after we have the ſtrongeſt convictions that it is impoſſible to bend the nature of things to our caprices and unfounded ideas, that ſome ſuperior mind diſengages itſelf from the deluſion; and returning to experiment, and the nature of things, ſuffers himſelf to be led no further than he is authorized by theſe to proceed.

We may affirm to the honour of ſome of our cotemporaries, that facts are at preſent diſcuſſed by a much ſeverer logic; and it is to this vigorous method of inveſtigation and diſcuſſion that we are indebted for the rapid progreſs of chemiſtry. It is in conſequence of this dialectic march that we have at length arrived to the practice of attending to all the principles which are combined or diſengaged in the operations of nature and art. We keep an account of all the circumſtances which have a more or leſs conſiderable influence on the reſults, and we deduce ſimple and natural conſequences from the whole of the facts; by which means we create a ſcience as ſtrict in its principles as ſublime in its applications.

This then is the moment to draw out a faithful ſketch of the actual ſtate of chemiſtry, and to collect in the numerous writings of modern chemiſts every thing which may ſerve to lay the foundation of this beautiful ſcience.

Not many years ago, it was poſſible to preſent, in a few words, the whole of our knowledge of chemiſtry. It was ſufficient, at that time, to point out the methods of performing pharmaceutical operations; the proceſſes of the arts were almoſt all enveloped in darkneſs, the phenomena of nature were all enigmatical; and

and it is only ſince this veil has begun to be removed that we have beheld the development of a collection of facts and reſearches referable to general principles, and forming a ſcience entirely new. Then it was that a number of men of genius reviewed the whole, and attended to the improvement of chemical knowledge. Every ſtep in their progreſs brought them nearer to the truth; and in a few years we have beheld a perſpicuous doctrine ariſe out of the ancient chaos. Every event has appeared conformable to the laws they eſtabliſhed; and the phenomena of art and nature are now explained with equal facility.

But in order to advance with ſpeed in the career which has been thus opened, it is neceſſary to explain certain principles, according to which we may direct our ſteps.

In the firſt place, I think it proper to avoid that tedious cuſtom which ſubjects the beginner in any ſcience to the painful taſk of collecting all the opinions of various philoſophers before he decides for himſelf. In reality, facts belong to all times, and are as unchangeable as nature herſelf, whoſe language they are. But the conſequences deduced from them muſt vary according to the ſtate of our acquired knowledge. It is eternally true, for example, that the combuſtion of ſulphur affords the ſulphuric acid. It was believed, for a certain time, that this acid was contained in the ſulphur; but our diſcoveries on the combuſtion of bodies ought to have led us to the deduction of a very different theory from that which preſented itſelf to the earlier chemiſts. We ought, therefore, to attach ourſelves principally to facts; or rather we ought to attach ourſelves to the facts only, becauſe the explanation which is given of them at remote times is very ſeldom ſuited to the preſent ſtate of our knowledge.

The numerous facts with which chemiſtry has been ſucceſſively enriched form the firſt embarraſſment of the ſtudent who is deſirous of acquiring the elements of this ſcience. In fact, what are the elements of ſcience? The clear, ſimple and accurate enunciation of thoſe truths which form its baſis. It is neceſſary, therefore, for the full accompliſhment of this purpoſe, to analyſe all the facts, and to exhibit a faithful and clear abridgment: but this method is impracticable on account of the numerous details, and the infinite number of diſcuſſions, into which it would lead us. The only proceeding, therefore, which appears to me to be practicable, is to exhibit the moſt deciſive experiments, thoſe which are the leaſt conteſted, ed, and to neglect thoſe which are doubtful or inconcluſive : for one experiment, well made, eſtabliſhes a truth as inconteſtably as a thouſand equally averred.

When a propoſition is found to be ſupported by ſuſpicious or conteſted facts, when oppoſite theories are built upon contradictory experiments, we muſt have the courage to diſcuſs them, to repeat them, and to acquire a certainty of the truth by our own endeavours. But when this method of conviction is out of our power, we ought to weigh the degree of confidence which the defenders of the oppoſite facts are entitled to ; to examine whether analogous facts do not lead us to adopt certain reſults ; after which it becomes us to give our opinion with that modeſty and circumſpection, ſuitable to the greater or leſs degree of probability annexed to each opinion.

But when any doctrine appears to us to be eſtabliſhed on experiments of ſufficient validity, it then remains to be applied to the phenomena of nature and art. This, in my opinion, is the moſt certain touchſtone to diſtinguiſh true principles from thoſe which are without foundation. And when I obſerve that all the phenomena of nature unite, and conform themſelves, as it were, to any theory, I conclude that this

this theory is the expreſſion and the language of truth. When, for example, I behold that a plant can be ſupported by pure water alone, that metals are calcinable, that acids are formed in the bowels of the earth, have I not a right to conclude that the water is decompoſed? and do not the chemical facts which in our laboratories afford a teſtimony of its decompoſition—do not theſe acquire a new force by the obſervation of the preceding phenomena? I conclude, therefore, that we ought to make a point of uniting theſe two kinds of proofs: and a principle deduced from experiment is not, in my opinion, demonſtrable, until I ſee that it may with facility be applied to the phenomena of art and nature. Hence, if I find myſelf in a ſtate of heſitation between oppoſite ſyſtems, I will decide in favour of that whoſe principles and experiments adapt themſelves naturally, and without force, to the greateſt number of phenomena. I will always diſtruſt a ſingle fact, which is applicable to no concluſion; and I will conſider it as falſe, if it be in oppoſition to the phenomena which nature preſents to us.

It appears to me likewiſe that he who profeſſes to ſtudy, or even to teach chemiſtry, ought not to endeavour to arrive at or exhibit the whole which has been done in each depart-

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ment, or to follow the tedious progreſs of the human mind from the origin of a diſcovery to the preſent time. This faſtidious erudition is fatiguing to the learner; and theſe digreſſions ought in no caſe to be admitted in the enunciation of ſcience, excepting when the hiſtorical details afford intereſting facts, or lead us by uninterrupted degrees to the preſent ſtate of our knowledge. It rarely happens, however, that this kind of reſearches, this genealogy of ſcience, affords us ſuch characters; and it ought no more to be admitted, in general, that an elementary writer ſhould bring together and diſcuſs every thing which has been done in a ſcience, than that he who undertakes to direct a traveller ſhould previouſly enter into a long diſſertation on all the roads which have been ſucceſſively made, and on thoſe which ſtill exiſt, before he ſhould point out the beſt and ſhorteſt way to arrive at the end of his journey. It may, perhaps, be ſaid of the hiſtory of ſcience, and more eſpecially that of chemiſtry, that it reſembles the hiſtories of nations. It ſeldom affords any light reſpecting the preſent ſituation of affairs; exhibits many fables concerning paſt times; induces a neceſſity of entering into diſcuſſions upon the circumſtances that paſs in review; and ſuppoſes a maſs of

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extraneous knowledge acquired on the part of the reader, which is independent of the purpoſe aimed at in the ſtudy of the elements of chemiſtry.

When theſe general principles, reſpecting the ſtudy of chemiſtry, are once well eſtabliſhed, we may afterwards proceed in the chemical examination of bodies in two ways: we may either proceed from the ſimple to the compound, or we may deſcend from the compound to the ſimple. Both theſe methods have their inconveniences; but the greateſt, no doubt, which is found in following the firſt method is, that, by beginning with the ſimpleſt bodies, we preſent ſubſtances to the conſideration of the learner which nature very ſeldom exhibits in ſuch a ſtate of nakedneſs and ſimplicity; and we are forced to conceal the ſeries of operations which have been employed to diveſt theſe ſubſtances from their combinations, and reduce them to the elementary ſtate. On the other hand, if we preſent bodies to the view of the learner ſuch as they are, it is difficult to ſucceed in an accurate knowledge of them; becauſe their mutual action, and in general moſt of their phenomena, cannot be underſtood without the previous and accurate knowledge of of their conſtituent principles, ſince it is upon theſe alone that they depend.

After having maturely conſidered the advantages and inconveniences of each method, we give the preference to the firſt. We ſhall therefore begin by giving an account of the ſeveral bodies in their moſt elementary ſtate, or reduced to that term beyond which analyſis can effect nothing; and, when we ſhall have explained their various properties, we will combine theſe bodies with each other, which will afford a claſs of ſimple compounds: and hence we ſhall riſe by degrees to the knowledge of bodies, and the moſt complicated phenomena. We ſhall be careful, in any examination of the ſeveral bodies to which we ſhall direct our reſearches, to proceed from known to unknown; and our firſt attention ſhall be directed to elementary ſubſtances. But as it is impoſſible, at one and the ſame time, to treat of all thoſe ſubſtances which the preſent ſtate of our knowledge obliges us to conſider as elementary, we ſhall confine ourſelves to the exhibition of ſuch as are of the greateſt importance in the phenomena of the globe we inhabit, ſuch as are almoſt univerſally ſpread over its ſurface, and ſuch as enter as principles into the compoſition of the re-agents moſt frequently employed in

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our operations; ſuch, in a word, as we continually find in the examination and analyſis of the component parts of the globe. Light, heat, ſulphur, and carbone are of this number. Light modifies all our operations, and moſt powerfully contributes to the production of all the phenomena which appertain to bodies either living or inanimate. Heat, diſtributed after an unequal proportion among all the bodies of this univerſe, eſtabliſhes their various degrees of conſiſtence and fixity; and is one of the great means which art and nature employ to divide and volatilize bodies, to weaken their force or adheſion, and by that means prepare them for analyſis. Sulphur exiſts in the products of the three kingdoms; it forms the radical of one of the beſt known, and moſt generally employed, acids; it exhibits intereſting combinations with moſt ſimple ſubſtances; and, under theſe ſeveral points of view, it is one of the ſubſtances the moſt neceſſary to be known in the firſt ſteps of chemical ſcience. The ſame may be ſaid of carbone; it is the moſt abundant fixed product found in vegetables and animals. Analyſis has diſcovered it in ſome mineral ſubſtances. Its combination with oxygene is ſo common in bodies, and in the operations of art and nature, that there are

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ſcarcely any phenomena which do not preſent it to our view, and which conſequently require the knowledge of its properties. From all theſe reaſons it appears to us, that for the advancement of chemiſtry it is neceſſary our firſt proceeding ſhould be founded on the knowledge of theſe ſubſtances; and that we ſhould not direct our attention to other ſimple or elementary ſubſtances, accordingly as they preſent themſelves.

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SECTION IV.

Concerning Simple or Elementary Subſtances.

IF we caſt an eye over the ſyſtems which have been ſucceſſively formed by philoſophers relative to the number and nature of the elements, we ſhall be aſtoniſhed at the prodigious variety which prevails in their manner of thinking. In the earlier times, every one ſeems to have taken his own imagination for his guide; and we find no reaſonable ſyſtem until the time when Ariſtole and Empedocles acknowledged as elements, Air, Water, Earth, and Fire. Their opinion has been well received for many ages; and it muſt be confeſſed that it is calculated to ſeduce the mind. There are, in fact, enormous maſſes, and inexhauſtible ſtores, that preſent themſelves to our view, of theſe four principles, to which the deſtruction or decompoſition of bodies appeared to refer all the ſeveral component parts which formation or creation had taken from them. The authority of all thoſe great men who had adopted this ſyſtem, and the analyſis of bodies which preſented

ſented only theſe four principles, afforded ſufficient grounds for admitting this doctrine.

But as ſoon as chemiſtry had advanced ſo far as to diſcover the principles of bodies, the profeſſors of that ſcience preſumed to mark the number, nature, and character of the elements; and every ſubſtance that was unalterable by the chemical methods of decompoſition, was conſidered by them as a ſimple or elementary principle. By thus taking the limits of analyſis as the term for indicating the elements, the number and the nature of theſe muſt vary according to the revolutions and the progreſs of chemiſtry. This has accordingly happened, as may be ſeen by conſulting all the authors who have written on this ſubject, from the time of Paracelſus to the preſent day. But it muſt be confeſſed that it is no ſmall degree of raſhneſs, to aſſume the extent of the power of the artiſt as a limit for that of the Creator, and to imagine that the ſtate of our acquiſitions is a ſtate of perfect knowledge.

The denomination of Elements ought therefore to be effaced from a chemical nomenclature, or at leaſt it ought not to be uſed but as an expreſſion denoting the laſt term of our analytical reſults; and it is always in this ſenſe that we ſhall uſe the word.

CHAP.

CHAP. I.

Concerning Fire.

THE principal agent employed by nature to balance the power and natural effect of attraction, is fire. By the natural effect of attraction we should possess none but solid and compact bodies; but the caloric unequally dispersed in bodies tends incessantly to destroy this adhesion of the particles; and it is to this principle that we are indebted for the varieties of consistence under which bodies present themselves to our observation. The various substances that compose this universe are therefore subjected, on the one hand, to a general law which tends to bring them together; and, on the other hand, to a powerful agent which tends to remove them from each other: it is upon the respective energy of these two forces that the consistence of all bodies depends. When the affinity prevails, they are in the solid state; when the caloric is most powerful, they are in the state of gas; and the liquid state appears to be the point of the equilibrium between these two powers.

It is therefore essentially necessary to treat of fire, since it acts so leading a part in this universe;

verſe; and becauſe it is impoſſible to treat of any ſubſtance whatever without attending to the influence of this agent.

There are two things to be conſidered in fire —heat and light.

Theſe two principles, which have been very often confounded, appear to be very diſtinct in their own nature; becauſe they are ſcarcely ever proportional to each other, and becauſe each can exiſt without the other.

The moſt uſual acceptation of the word Fire comprehends heat and light; and its principal phenomena muſt have been known for a long time. The diſcovery of fire muſt have been nearly as ancient as the human ſpecies upon this globe. The ſhock of two flints, the action of meteors, or the effect of volcanoes, muſt have afforded the earlieſt idea of it; and it is very aſtoniſhing that the inhabitants of the Marian Iſlands were not acquainted with its effects before the invaſion of the Spaniards. Theſe iſlanders, who became acquainted with this terrible element only in conſequence of its ravages, conſidered it at firſt as a malevolent being which attached itſelf to all beings, and devoured them.—See the Abbé Raynal's Hiſtoire Philoſophique, &c.

The effects of fire are perhaps the moſt aſtoniſhing nifhing of any which nature exhibits; and we ought not to be furprifed that the ancients confidered it as an intermediate being between fpirit and matter, and have built the beautiful fable of Prometheus upon its origin. We have had the happinefs, in our time, to acquire well-founded and extenfive ideas refpecting this agent, which we fhall proceed to develop in the two following articles.

ARTICLE I.

Concerning Caloric and Heat.

When a metal or a liquid is heated, thefe bodies are dilated in every direction, are reduced to vapour, and at laft become invifible when the moft powerful heat is applied to them.

Bodies which poffefs the principle of heat, part with it more or lefs readily. If we attentively obferve a body during its cooling, a flight movement of undulation will be perceived in the furrounding air; an effect which may be compared to the phenomenon exhibited upon the mixture of two liquors of unequal denfity and weight.

It is difficult to conceive this phenomenon without admitting of a peculiar fluid, which paffes firft from the body which heats to that which

which is heated, combines with the latter, produces the effects we have ſpoken of, and afterwards eſcapes to unite with other bodies, according to its affinities, and the law of equilibrium, to which all bodies tend.

This fluid of heat, which we call Caloric, is contained in greater or leſs quantities in bodies, according to the greater or leſs degrees of affinity exiſting between it and them.

Various means may be employed to diſplace or diſengage the caloric. The firſt is by the method of affinities: for example, water poured upon the ſulphuric acid expels the heat, and takes its place; and while there is a diſengagement of heat, the volume of the mixture does not increaſe in proportion to the bulk of the two ſubſtances mixed. This ſhews that penetration takes place, which cannot be explained but by admitting that the integrant parts of the water take the place of the caloric, in proportion as it is diſſipated.—The ſecond method of precipitating caloric, is by friction and compreſſion. In this caſe it is expreſſed or ſqueezed out, in the ſame manner as water from a ſponge. In reality, the whole of the heat which may be produced by friction, is not afforded by the body itſelf; becauſe, in proportion as the interior heat is developed, the external air acts upon the body, calcines or inflames it, and itſelf gives out heat during its fixation. Fermentation, and in general every operation which changes the nature of bodies, may diſengage caloric, becauſe the new compound may demand and receive a greater or leſs quantity. Hence it is that chemical operations produce ſometimes cold, and ſometimes heat.

Let us now examine the form under which caloric preſents itſelf.

This fluid is diſengaged either in a ſtate of liberty, or in a ſtate of combination.

In the firſt caſe, the caloric always endeavours to obtain an equilibrium; not that it is diſtributed equally among all bodies, but it is diſperſed among them according to the degrees of its affinity. Whence it follows, that the circumambient bodies receive and retain a quantity more or leſs conſiderable. Metals are eaſily penetrated by this fluid, and tranſmit it with equal facility; wood and animal ſubſtances receive it to the degree of combuſtion; liquids, until they are reduced to vapour. Ice alone abſorbs all the heat communicated to it, without giving it out to other bodies until it has acquired the fluid ſtate*.

* The ingenious author has inadvertently been guilty of an overſight. Not only ice, but all other bodies, abſorb heat during liquefaction, as he himſelf ſhews hereafter. T.

The

The degree of heat can be appreciated only by its effects: and the inftruments which have been fucceffively invented to calculate it, and are known by the names of thermometers, pyrometers, &c. have been applied to the ftrict determination of the feveral phenomena exhibited in confequence of the abforption of caloric in various bodies.

The dilatation of fluids, or of metals in the fluid ftate, by the feveral degrees of heat, has been long meafured by thermometers formed of glafs; but this very fufible fubftance can only be ufed to afcertain degrees of heat inferior to that which renders the glafs itfelf fluid.

Several means have been fucceffively propofed for calculating the higher degrees of heat. Mr. Leidenfroft has proved that the hotter a metal is, the more flowly will drops of water evaporate from its furface; and he has propofed this principle for the conftruction of pyrometers. A drop of water in an iron fpoon, heated to the degree of boiling water, evaporates in one fecond; a fimilar drop, poured on melted lead, is diffipated in fix or feven feconds; and upon red-hot iron in thirty. Mr. Ziegler, in his Specimen de Digeftore Papini, has found that 89 feconds were required to evaporate a drop of water at 520 degrees of Fahrenheit; and that

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one ſecond is ſufficient at the 300dth degree. This phenomenon, which is more intereſting to chemiſtry than pyrometry, to which it will always afford reſults little ſuſceptible of rigorous calculation, appears to me to depend upon the adheſion and decompoſition of the water upon the metal.

The moſt accurate pyrometer we are acquainted with, is that which was preſented to the Royal Society of London by Mr. Wedgwood. It is conſtructed upon the principle, that the pureſt clay ſhrinks in the fire in proportion to the heat applied to it. This pyrometer conſiſts of two parts; one called the gauge, which ſerves to meaſure the degrees of diminution or ſhrinking; the other contains the ſimple pieces of pure clay, which are called thermometer pieces.

The gauge is formed of a plate of baked earth, upon which are applied two rulers or ſtraight pieces of the ſame ſubſtance. Theſe rulers, being perfectly ſtraight and even, are placed at the diſtance of half an inch from each other at one of their ends, and three-tenths of an inch at the other. For greater convenience, the gauge is divided into two parts, and the two pieces are placed endways when required to be uſed. The length of this rule is divided into

240 equal parts, of which each reprefents one-tenth of an inch*. To form the thermometer pieces, the earth is fifted with the greateft attention, after which it is mixed with water, and the pafte thruft through an iron tube, which gives it a cylindrical form, to be cut afterwards into pieces of a proper fize. When the pieces are dry, they muft be prefented to the gauge, where they ought to fit at the place of 0 on the fcale. If by inadvertence of the workmen any piece penetrates to one or two degrees further, this degree is marked on its flat furface, and requires to be deducted when the piece is ufed in the admeafurement of heat. The pieces thus adjufted are baked in a furnace to a red heat, to give them the confiftence neceffary for carriage. The heat employed in this part of the procefs is ufually about fix degrees, and the pieces are diminifhed more or lefs; but this is of no confequence when they come to be fubmitted to a fuperior degree of heat; and if it fhould happen that an inferior degree of heat is required to be meafured, unbaked pieces are to be ufed, which are preferved in fheaths or cafes to avoid friction.

When this pyrometer is to be ufed, one of the

* This is, in fact, the twelve-hundredth of an inch in the width, according to the dimenfions here given. T.

the pieces is expofed in the fire-place whofe heat is required to be determined; and when it has acquired the whole intenfity, it is taken out, and fuffered to cool, or for greater fpeed it is plunged in water; after which it is prefented to the gauge, and its degree of contraction eafily determined. Mr. Wedgwood has given us the refult of feveral experiments made with his pyrometer, oppofite to which he has placed the correfpondent degrees of Fahrenheit,

		Pyrometer of Wedgwood.	Thermometer of Fahrenheit.
Red heat vifible by the light		0	1077
Brafs melts at		21	1857
Swedifh copper melts at		27	4587
Pure filver melts at		28	4717
Pure gold melts at		32	5237
The heat of bars of iron raifed to welding	fmall bar	90	12777
	large bar	95	13427
The greateft heat producible in a fmith's forge		125	17327
Caft iron melts at		130	17977
The greateft heat of a wind furnace of eight inches fquare		160	21877

Thefe various thermometers are not applicable to all cafes. We cannot, for example, calculate with ftrictnefs the heat which efcapes from living bodies, or determine with precifion the temperature of any fubftance. But Meffrs. De la Place and Lavoifier (Acad. des Sciences, 1780) have invented an apparatus which appears to leave nothing further to be defired. It

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is conſtructed upon the principle that ice abſorbs all the heat communicated to it, without communicating it to other bodies until the whole is melted; ſo that from hence we may calculate the degrees of heat communicated, by the quantity of ice which is melted. It was neceſſary, in order to afford ſtrict reſults, to diſcover the means of cauſing the ice to abſorb all the heat diſengaged from the bodies under examination, and to cover it from the action of every other ſubſtance which might facilitate its fuſion; and, laſtly, to collect with great care the water produced by the fuſion.

The apparatus conſtructed by theſe two celebrated academicians for this purpoſe, conſiſts of three circular veſſels nearly inſcribed in each other; ſo that three capacities are produced. The interior ſpace or capacity is formed by an iron grating, upon ſupports of the ſame metal. Here it is that the bodies ſubjected to experiment are placed. The upper part of this cavity is cloſed by means of a cover. The middle ſpace, next to this, is deſigned to contain the ice which ſurrounds the interior compartment. This ice is ſupported and retained by a grate, upon which a cloth is ſpread. In proportion as the ice melts, the water flows through the grate and the cloth, and is collected in a

veſſel

veſſel placed beneath. Laſtly, the external ſpace or compartment of the apparatus contains ice intended to prevent the effect of the external heat of the atmoſphere.

To uſe this excellent machine, the middle or ſecond ſpace is filled with pounded ice, as is likewiſe the cover of the internal ſphere; the ſame thing is done with regard to the external ſpace, as well as to the general covering of the whole machine: the interior ice is ſuffered to drain; and, when it ceaſes to afford water, the covering of the internal ſpace is raiſed, to introduce the body upon which the experiment is intended to be made. Immediately after this introduction, the covering is put on, and the whole apparatus remains untouched until the included body has acquired the temperature of 0, or the freezing temperature of water, which is the common temperature of the internal capacity. The quantity of water afforded by the melting of the ice is then weighed; and this is an accurate meaſure of the heat diſengaged from the body, becauſe the fuſion of the ice is the effect of this heat only. Experiments of this kind laſt fifteen, eighteen, or twenty hours.

It is of great conſequence, that in this machine there ſhould be no communication between

tween the middle, or second, and the external space.

It is likewise necessary that the air of the apartment should not be lower than 0, because the interior ice would then receive a degree of cold lower than that temperature.

Specific heat is merely the proportional quantity of heat necessary to raise bodies of equal mass to the same number of degrees of temperature: so that, when the specific heat of a solid body is required, its temperature must be elevated a certain number of degrees, at which instant it must be placed in the internal sphere, and there left until its temperature is reduced to 0. The water is then collected, and this quantity divided by the product of the mass of the body; and the number of degrees of its original temperature above 0, will be proportional to its specific heat.

With regard to fluids, they are inclosed in vessels whose heat has been previously determined. The operation is then the same as for solids; excepting that the quantity of water afforded must be diminished by a deduction of that quantity which has been melted by the heat of the vessel.

If it be required to determine the heat which is disengaged during the combination of various substances,

ſubſtances, they muſt be all reduced, as well as their containing veſſels, to the temperature of o. The mixture muſt then be placed in the internal ſphere; and the quantity of water collected is the meaſure of the diſengaged heat.

In order to determine the heat of combuſtion and reſpiration, as the renewal of air is indiſpenſable in theſe two operations, it is neceſſary to eſtabliſh a communication between the internal part of the ſphere and the ſurrounding atmoſphere; and in order that the introduction of freſh air may not cauſe any perceptible error, theſe experiments ought to be made at a temperature little differing from o, or at leaſt the air which is introduced muſt previouſly be brought to this temperature.

To determine the ſpecific heat of any gas, it is neceſſary to eſtabliſh a current through the internal part of the ſphere, and to place two thermometers, one at the place of introduction, and the other at the place of eſcape. By compariſon of the temperatures exhibited by theſe two inſtruments, a judgment is formed of the heat abſorbed, and the melted ice is meaſured.

An excellent memoir of Meſſrs. De la Place and Lavoiſier may be conſulted for the reſults of the experiments they have made. The preſent extract contains only a ſhort account of their valuable labours.

The

The various means made uſe of for the admeaſurement of heat, are founded on the general principle, that different bodies abſorb heat in greater or leſs quantities. If this fact were not generally admitted, it might be eſtabliſhed on the three following facts. Dr. Franklin having expoſed two ſmall pieces of cloth, of the ſame texture but of different colours, upon the ſurface of ſnow, perceived a few hours afterwards, that the red cloth was buried in the ſnow, while the other which was white had not ſuffered any depreſſion*. M. de Sauſſure obſerves, that the peaſants of the mountains of Switzerland are careful to ſpread a black earth over the ſurface of grounds covered with ſnow, when they are deſirous of melting it to ſow their ſeed. So likewiſe children burn a black hat in the focus of a ſmall lens which would ſcarcely heat a white one.

Such nearly are the phenomena of heat when it is diſengaged in a ſtate of liberty. Let us now contemplate thoſe which it preſents when it eſcapes from a ſtate of combination.

Heat is ſometimes diſengaged in a ſtate of ſimple mixture, as in the phenomena of vapours, ſublimations, &c. If heat be applied to water, theſe two fluids will unite, and the mixture

* They were expoſed to the rays of the ſun. T.

ture will be diſſipated in the atmoſphere ; but it would be an abuſe of words to call ſo weak an union by the name of combination : for, as ſoon as the heat becomes in a ſituation to combine with other bodies, it abandons the water, which returns to a liquid ſtate. This body, during evaporation, continually carries with it a portion of heat ; and hence, perhaps, reſult the advantages of tranſpiration, perſpiration, &c.

But heat very frequently contracts a true chemical union with the bodies which it volatilizes: this combination is even ſo perfect, that the heat is not perceptible, but it is neutralized by the body with which it is combined. It is then called latent heat, *calor latens*.

The ſeveral caſes in which heat enters into combination, and paſſes to the ſtate of latent heat, may be reduced to the two following principles:

The firſt principle.—Every body which paſſes from the ſolid to the liquid ſtate, abſorbs a portion of heat, which is no longer ſenſible to the thermometer, but exiſts in a true ſtate of combination.

The academicians of Florence filled a veſſel with pounded ice, and plunged a thermometer in it, which deſcended to o. The veſſel was then immerſed in boiling water, and the ther-

mometer

mometer did not riſe during the whole time of the liquefaction of the ice. The fuſion of ice therefore abſorbs heat.

Mr. Wilcke poured a pound of water, heated to the 60th degree of Reaumur, upon a pound of ice. The melted mixture poſſeſſed the temperature of 0. Sixty degrees of heat had therefore entered into combination.

The chevalier Laudriani has ſhewn that the fuſion of metals, of ſulphur, of phoſphorus, of alum, of nitre, &c. abſorbs heat.

Cold is produced in the diſſolution of all the (cryſtallized) ſalts.

Reaumur made a ſeries of very intereſting experiments on this ſubject, which confirm thoſe of Boyle. Fahrenheit cauſed the thermometer to deſcend to forty degrees, by melting ice by ſtrong nitrous acid. But the moſt aſtoniſhing experiments are thoſe made by Meſſrs. Thomas Beddoes*, phyſician, and Walker, apothecary at Oxford, and inſerted in the Philoſophical Tranſactions for the year 1787†. The mixtures which produced the greateſt degrees of cold are,

* It does not appear that Dr. Beddoes either had or pretends to have any other ſhare in the experiments of Mr. Walker, than that of having tranſmitted them to the Royal Society. T.

† Alſo in the ſubſequent volumes.

1. Eleven

1. Eleven parts of muriate of ammoniac, or common ſal ammoniac; ten parts of nitrate of pot-aſh, or common nitre; ſixteen parts of ſulphate of ſoda, or Glauber's ſalt; with thirty-two parts by weight of water: the two firſt ſalts ſhould be dry, and in powder. 2. The nitric acid, muriate of ammoniac, and ſulphate of ſoda, lowered the thermometer to eight degrees under 0. Mr. Walker has frozen mercury without uſing either ice or ſnow.

It is therefore an incontrovertible principle, that all bodies which paſs from the ſolid to the liquid ſtate, abſorb heat, and retain it in ſo accurate a combination as to afford no ſign of its preſence. The heat is therefore fixed, neutralized, or latent.

The ſecond principle.—All bodies, by paſſing from the ſolid or fluid ſtate to the aëriform ſtate, abſorb heat, which becomes latent; and it is by virtue of this heat that ſuch bodies are placed and maintained in that ſtate.

On this principle is founded the proceſs uſed in China, India, Perſia, and Egypt, to cool liquors uſed for drink.

The water intended for this purpoſe is put into very porous veſſels, and expoſed to the ſun, or to a current of warm air, to cool the fluid contained within them.

It

It is by ſimilar means that cool drink is obtained in the long journeys of the caravans. Intereſting details on this ſubject may be ſeen in the Travels of Chardin, vol. iii. 1723; Tavernier's Voyages, vol. i. edit. 1738; Paul Lucas's Voyages, vol. ii. edit. 1724; and alſo in the Mundus Subterraneus of P. Kircher, lib. vi. ſec. 2. cap. 2.

We may conclude from the experiments of Mr. Richmann, made in 1747, and inſerted in the firſt volume of the Imperial Academy of Peterſburgh, 1. That a thermometer taken out of water, and expoſed to the air, always deſcends, even when its temperature is equal or ſuperior to that of the water. 2. That it afterwards riſes, until that it has acquired the temperature of the atmoſphere. 3. That the time of deſcending is leſs than that which it employs to riſe again. 4. That when the thermometer, withdrawn from the water, has ariſen to the common temperature, its bulb is dry; but that it continues wet during the whole time of its ſtanding beneath this common temperature.

To theſe conſequences we will add others deduced from ſeveral curious experiments by the celebrated Cullen. 1. A thermometer ſuſpended in the receiver of the air pump, deſcends two or three degrees during the time of exhauſtion, exhauftion, and afterwards rifes to the temperature of the vacuum. 2. A thermometer plunged in alcohol, in the receiver of the air pump, always defcends, and the lower in proportion as the bubbles are ftronger which iffue from the alcohol; if it be withdrawn from this liquor, and fufpended wet beneath the receiver, it falls eight or ten degrees while the air is pumping out.

It is well known that if the ball of a thermometer be wrapped in fine linen, and kept moift by fprinkling with ether, and the evaporation be facilitated by agitation in the air, the thermometer will defcend to 0.

The immortal Franklin has proved, in his own perfon, that when the body perfpires ftrongly, it is lefs heated than furrounding bodies, and that perfpiration always produces a certain degree of coldnefs.—See his Letter to Dr. Lind.

The great number of labourers in the burning heats of our climate fupport themfelves only by virtue of a copious perfpiration, the fluid for which they replenifh by drinking plentifully. The workmen employed in glafs-houfes, founderies, &c. often live in a medium hotter than their bodies, the natural temperature of which is equalized and moderated by perfpiration.

If evaporation be increafed by agitation of

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the air, the refrigeration is the greater. Hence the uſe of fans, ventilators, &c. which, though intended to give motion to warm air, afford likewiſe the virtue of cooling by facilitating and favouring evaporation.

Warm and dry air is beſt ſuited to form a refreſhing current, becauſe it is more calculated to diſſolve and abſorb humidity; moiſt air is leſs proper, becauſe it is already ſaturated.—Hence the neceſſity of frequently renewing the air to preſerve the coolneſs of our apartments.

Theſe principles have a nearer relation to medicine than is generally ſuppoſed. We find that almoſt all fevers end in perſpirations, which, beſide the advantage of expelling the morbific matter, poſſeſs likewiſe that of carrying off the matter of heat, and reſtoring the body to its common temperature. The phyſician who is deſirous of moderating the exceſs of heat in the body of a patient, ought to maintain the air in that diſpoſition which is moſt ſuitable to his views.

The uſe of volatile alkali is univerſally acknowledged to be of advantage in burns, the tooth-ach, &c. May not theſe effects be attributed to the volatility of this ſubſtance, which quickly combining with heat, carries it off, and leaves an impreſſion of cold?—Ether is a ſovereign remedy for the colic. Does not its virtue depend on the ſame principles?

The heat which has entered into combination with bodies during their tranſition from the ſolid to the liquid ſtate, or from this laſt to the aëriform ſtate, may be again exhibited by cauſing theſe ſubſtances to return again to the ſtates of liquefaction or ſolidity. In a word, every ſubſtance which paſſes from the liquid to the ſolid ſtate, ſuffers its latent heat to eſcape, which at this inſtant becomes free or thermometrical heat.

The celebrated Fahrenheit, in the year 1724, having left water expoſed to a colder temperature than that of ice, the water remained fluid: but it congealed by agitation; and the thermometer, which marked ſeveral degrees beneath the freezing point, ſuddenly roſe to that temperature. Mr. Treiwald mentions a ſimilar fact in the Tranſactions; and Mr. De Ratte made the ſame obſervation at Montpelier.

Mr. Baumé has ſhewn, in his enquiries and experiments relating to ſeveral ſingular phenomena exhibited by water at the inſtant of its congelation, that ſeveral degrees of heat are always developed at that inſtant.

Gaſeous ſubſtances are maintained in the aëriform ſtate merely by the heat which is combined

bined with them; and when to these substances, thus dissolved in caloric, another body is presented, to which they have a very strong affinity, they abandon their heat to unite with this last substance; and the caloric, thus expelled or disengaged, appears under the form of free or thermometrical heat. This disengagement of heat, by the concretion or fixation of gaseous substances, was observed by the celebrated Scheele, as may be seen in the valuable experiments which form the basis of his Treatise on Air and Fire. Since the time of this great man, rigorous calculations have been made of the quantity of latent heat existing in each of these gases: we are indebted to Messrs. Black, Crawford, Wilcke, De la Place, Lavoisier, &c. for many excellent researches on this subject.

ARTICLE II.

Concerning Light.

It appears that Light is transmitted to our eyes by a peculiar fluid which occupies the interval between us and visible bodies.

Does this fluid arrive directly from the Sun by successive emissions or eradiations? or is it a peculiar fluid diſtributed through ſpace, and put in action by the Sun's rotary motion, or by any other cauſe? I ſhall not enter into any diſcuſſion upon this ſubject, but ſhall confine myſelf to point out the phenomena.

A. The motion of light is ſo rapid, that it paſſes through nearly eighty thouſand leagues in a ſecond.

B. The elaſticity of the rays of light is ſuch, that the angle of reflection is equal to the angle of incidence.

C. The fluid of light is ponderous; for if a ray of light be received through a hole in a window-ſhutter, and the blade of a knife be preſented to it, the ray is diverted from a right line, and is inflected towards the body. This circumſtance ſhews that it obeys the law of attraction, and ſufficiently authoriſes us to claſs it among other bodies of this nature.

D. The great Newton ſucceeded in decompoſing the ſolar light into ſeven primitive rays, which preſent themſelves in the following order: red, orange, yellow, green, blue, indigo, violet. Dyes preſent us with only three colours, which are red, blue, and yellow; the combinations and proportions of theſe three principles form all the ſhades of colour with which the arts are enriched. Philoſophers have maintained that

among

among the ſolar rays there are three primitive colours.—See Les Recherches de M. Marat.

All natural bodies may be conſidered as priſms which decompoſe or rather divide the light. Some reflect the rays without producing any change, and theſe are white; others abſorb them all, and cauſe abſolute blackneſs: the greater or leſs affinity of the ſeveral rays with various bodies, and perhaps likewiſe the diſpoſition of the pores, is no doubt the cauſe that, when a pencil falls upon a body, ſome rays enter into combination, while others are reflected; and it is this which affords the diverſity of colours, and the prodigious variety of ſhades under which bodies appear to our eyes.

We can no longer confine ourſelves to conſider light as a merely phyſical ſubſtance; the chemiſt perceives its influence in moſt of his operations, and finds it neceſſary to attend to its action, which modifies his reſults; and its effects are no leſs evident in the various phenomena of nature, than in the experiments performed in our laboratories.

We ſee that vegetation cannot take place without light. Plants deprived of this fluid become pale; and when in hot-houſes the light comes to them from one part only, the vegetables incline towards the aperture, as if to ſhew the neceſſity of this beneficial fluid.

Without

Without the influence of light, vegetables would exhibit but one lifelefs colour; they are deprived of their beautiful fhades by the interception of this luminous fluid. On thefe principles, celery, endive, and other plants, are bleached.

Vegetables are not only indebted to the light for their colour, but likewife for their fmell, tafte, combuftibility, maturity, and the refinous principle, which equally depend upon this fluid. Hence it is, no doubt, that aromatic fubftances, refins, and volatile oils, are the inheritance of fouthern climates, where the light is more pure, conftant, and intenfe.

We fee, likewife, that the influence of light is evident in other beings: for, as Mr. Dorthes has obferved, worms and grubs, which live in the earth or in wood, are of a whitifh colour. The birds and flying infects of the night are likewife diftinguifhable from thofe of the day by the want of brilliancy of colour; and the difference is equally marked between thofe of the north and of the fouth.

A very aftonifhing property of light upon the vegetable kingdom is, that when vegetables are expofed to open day-light, or to the fun's rays, they emit vital air. We fhall again attend to all thefe phenomena when we come to treat of the analyfis of vegetables.

The

The fine experiments of Scheele and Berthollet have ſhewn that the abſence or preſence of light has an aſtoniſhing effect upon the reſult of chemical experiments. Light diſengages vital air from ſeveral fluids, ſuch as the nitric acid, the oxigenated marine acid, &c. It reduces the oxides or calces of gold, ſilver, &c. It changes the nature of oxigenated muriates, according to the obſervations of Mr. Berthollet. Light likewiſe determines the phenomena of vegetation exhibited by ſaline ſolutions, as I have ſhewn. From all which circumſtances it is evident that we ought to attend to the effect of this agent in almoſt all our operations.

" Organization, ſenſation, ſpontaneous motion, and life, exiſt only at the ſurface of the earth, and in places expoſed to light: we might affirm that the flame of Prometheus's torch was the expreſſion of a philoſophical truth which did not eſcape the ancients. Without light, nature was lifeleſs, inanimate, and dead: a benevolent God, by producing light, has ſpread organization, ſenſation, and thought over the ſurface of the earth."—Elementary Treatiſe of Chemiſtry by Mr. Lavoiſier.

We ought not to confound the ſolar light with the light of our furnaces; the light of theſe thefe has, as I am convinced, very evident effects in certain phenomena; but thefe effects are flow, and fcarcely comparable with thofe of the folar light.

Although heat often accompanies light, the phenomena we have mentioned cannot be attributed to mere heat. Heat may indeed modify them where it exifts, but moft affuredly it cannot produce them.

CHAP. II.

Concerning Sulphur.

WE are obliged to place Sulphur among the elements, though our predeceffors pretended to have determined its conftituent principles. This proceeding would appear to be retrograde, if it were not evident that the correction of miftakes is a real advancement in fcience.

The ancients ufed the word fulphur to denote every combuftible and inflammable fubftance. Accordingly we find, in all their writings, the expreffions of fulphur of metals, fulphur of animals, fulphur of vegetables, &c.

Stahl affigneth a determinate value to the denomination of Sulphur; and fince the time of this

this celebrated chemiſt we have confined the name to denote a body of an orange-yellow colour, dry, brittle, capable of burning with a blue flame, and exhaling a penetrating odour during combuſtion: when rubbed, it becomes electric; and by a light preſſure in the hand it cracks, and becomes reduced to powder.

It appears that ſulphur is formed by the decompoſition of vegetables and animals. It has been found on the walls of neceſſary-houſes; and when the ditch of the Port St. Antoine, at Paris, was cleared, a conſiderable quantity was collected, which was mixed with the decayed remains of vegetable and animal ſubſtances, that had filled the ancient ditches, and there putrefied.

Mr. Deyeux has likewiſe proved, that ſulphur exiſts naturally in certain plants, ſuch as patientia, cochlearia, &c. His proceſſes for extracting it conſiſt in—1. The waſhed root muſt be reduced by raſping into a fine pulp; this muſt be waſhed in cold water, and paſſed through a ſieve or cloth of an open texture; the fluid paſſes in a turbid ſtate, and depoſits a precipitate, which when dried proves the exiſtence of ſulphur. 2. The pulp may be boiled, and the ſcum afforded by the ebullition afterwards dried: this ſcum contains ſulphur. Se-

veral

veral ſpecies of rumex, confounded under the name of Patience, do not contain ſulphur. I have obtained it from the rumex patientia L. which grows on the mountains Cevennes, and is the ſame which is uſed at Paris. M. Le Veillard obtained ſulphur by ſuffering vegetable ſubſtances to putrefy in well-water. Sulphur is abundantly contained in coal mines; it is found in combination with certain metals; it appears almoſt always where vegetable decompoſition takes place; it forms the greater part of thoſe pyritous and bituminous ſchiſti which occupy the focus of volcanos; it is ſublimed in thoſe places where the pyrites are decompoſed; it is thrown out by ſubterraneous fires; and is found in greater or leſs quantities in volcanic diſtricts. Much has been ſaid concerning ſhowers of ſulphur; but it is at preſent well known that this error has chiefly ariſen from the powder of the ſtamina of the pine, which is carried to great diſtances. Henckel ſaw the ſurface of a marſh entirely covered with this powder.

The known proceſſes for extracting ſulphur in the large way, and applying it to the purpoſes of commerce, conſiſt in diſengaging it from the pyrites or ſulphures of copper, or of iron, by methods poſſeſſing various degrees of ſimplicity and economy. On this ſubject, the

Pyritology

Pyritology of Henckel, Macquer's Chemical Dictionary, and the Metallurgical Tracts of Mr. Jars, may be confulted.

In Saxony and Bohemia the ores of fulphur are diftilled in earthen tubes difpofed in a gallery. The fulphur which is difengaged by the heat paffes into receivers placed without, and in which care is taken to keep a fufficient quantity of water.

At Rammelfberg, at St. Bel, &c. large heaps of pyrites are made, which are decompofed by a gentle heat, at firft applied to the mafs from a ftratum of combuftible matter upon which it is placed. The heat is afterwards kept up by the action of the pyrites amongft each other. The fulphur which exhales cannot efcape laterally, becaufe care is taken to cover the fides with earth. It therefore rifes to the fummit of the truncated pyramid, where it is collected into fmall cavities made for that purpofe. The heat of this part is fufficient to keep the fulphur in a fluid ftate; and it is taken out from time to time with ladles.

Almoft all the fulphur ufed in France comes from the Solfatara. This volcanic country every where exhibits marks of the agency of fubterraneous fire. The enormous maffes of pyrites which are decompofed in the bowels of the earth produce heat, which fublimes part of the fulphur ſulphur through apertures which the fire, and the effort of the vapours, have opened in all parts. The earths and ſtones which contain ſulphur are diſtilled; and it i the reſult of this diſtillation which is called Crude Sulphur.

The crude ſulphur is tranſported into France by the way of Marſeilles, where it receives the neceſſary preparations to render it ſuitable to various purpoſes. 1. It is reduced into ſticks or rolls, by fuſing it, and pouring it into moulds: or, 2. It is formed into flowers of brimſtone by ſubliming it with a gentle heat, and collecting this ſulphureous vapour in a very cloſe chamber of conſiderable extent. This very pure and finely divided ſulphur is diſtinguiſhed by the name of Flowers of Brimſtone, or Sublimed Sulphur.

Sulphur enters into fuſion by a moderate heat; and if the moment be ſeized in which the ſurface congeals, and the liquid ſulphur contained beneath that ſurface be then poured out, the internal cavity will exhibit long needle-formed cryſtals of an octahedral figure. This proceſs, contrived by the famous Rouelle, has been applied to the cryſtallization of almoſt all the metals. Sulphur is found naturally cryſtallized in Italy, at Conilla near Cadiz, &c. Its uſual form is octahedral; but I have ſeen cryſtals of ſulphur in perfect rhomboids.

Stahl

Stahl thought that he had proved, by analyſis and ſyntheſis, that ſulphur is formed by the combination of his phlogiſton with the ſulphuric acid. The happy ſeries of proofs which he has left behind him for the eſtabliſhment of this opinion, has appeared ſo complete, that, ſince the time of this great man, his doctrine has conſtantly been admitted as founded on abſolute proof. This example was even urged as an inſtance to ſhew how high a degree of evidence the chemical analyſis was capable of affording. But our diſcoveries reſpecting gaſeous ſubſtances have ſhewn us, that the ancients were neceſſarily led into error for want of that knowledge. The immenſe reſearches of the moderns into the compoſition of acids, have ſhewn that theſe ſubſtances are decompoſed in a variety of operations; and this revolution in the ſtate of our knowledge muſt have produced a ſimilar change in our methods of explaining the phenomena. An examination of the principal experiments of Stahl, upon which his doctrine eſſentially depends, will ſufficiently ſhew the truth of what we have aſſerted.

If one third part of charcoal, and two thirds of ſulphate of pot-aſh, or vitriolated tartar, be mixed and fuſed in a crucible, the product is (liver of ſulphur) ſulphure of pot-aſh. If this ſulphure

phure be diffolved in water, and the alkali be engaged by adding a few drops of fulphuric acid, a precipitate is afforded, which confifts of true fulphur: "whence," fays Stahl, "the fulphur is a combination of phlogifton, or the inflammable principle of the charcoal with the fulphuric acid." The experiment was true, but the confequence is abfurd; becaufe it would follow that the fulphuric acid which was added, muft have poffeffed the property of difplacing fulphuric acid united to the alkali *.

If Stahl had more ftrictly analyfed the refult or product of this operation, he would have been convinced that it does not contain a particle of fulphuric acid.

If he had been poffeffed of the power of operating in clofed veffels, and of collecting the gafeous fubftances which are difengaged, he would have obtained a large quantity of carbonic acid, which arifes from the combination of the oxigene of the fulphuric acid with charcoal.

* Without pretending, on the prefent occafion, to difpute either for or againft phlogifton, I fhall obferve that this argument is one among the many paralogifms urged on both fides in this controverfy. If there be any difficulty in conceiving how dephlogifticated fulphur, or pure vitriolic acid, may difplace phlogifticated vitriolic acid, or fulphur, the fame will apply to the oppofite theory, which afferts that aërated fulphur, or vitriolic acid, difplaces de-aërated vitriolic acid, or pure fulphur. T.

If

If he had expoſed his liver of ſulphur to the air in cloſed veſſels, he would have ſeen that the vital air is abſorbed, that the ſulphure is decompoſed, and that the ſulphate of pot-aſh, or vitriolated tartar is formed; which proves the recompoſition of the ſulphuric acid.

If charcoal be moiſtened with ſulphuric acid or oil of vitriol, and then expoſed to diſtillation, the products are carbonic acid or fixed air, ſulphur, and much ſulphureous or volatile vitriolic acid.

The experiments of Stahl exhibit the moſt perfect demonſtration of the decompoſition of the ſulphuric acid into ſulphur and oxigene; and it is not neceſſary, in the explanation of them, either to ſuppoſe the exiſtence of an imaginary being, or to ſuppoſe that ſulphur is a compounded body.

CHAP. III.

Concerning Carbone.

PURE charcoal is called Carbone in the new Nomenclature. This ſubſtance is placed among ſimple bodies, becauſe no experiment has hitherto ſhewn the poſſibility of decompoſing it.

Carbone

Carbone exifts ready formed in vegetables. It may be cleared of all the volatile and oily principles by diftillation; and, by fubfequent wafhing in pure water, it may be deprived of all the falts which are mixed and confounded with it.

When it is required to procure carbone in a ftate of great purity, it muft be dried by ftrong ignition in a clofed veffel: this precaution is neceffary; for the laft portions of water adhere with fuch avidity, that they are decompofed, and afford hydrogenous gas and carbonic acid.

Carbone exifts likewife in the animal kingdom: it may be extracted by a procefs fimilar to that which we have defcribed; but its quantity is fmall. It appears in the form of a light fpongy mafs, difficultly confumed in the air, and mixed with a great quantity of phofphates, and even of fodar.

Carbone is likewife found in plumbago, of which it is one of the principles.

We fhall treat more fully of this fubftance in the analyfis of vegetables. But thefe concife ideas are fufficient to enable us to proceed in our account of its combinations, which is indeed the only object of the prefent fhort enumeration of its properties.

SEC-

SECTION V.

Concerning Gaſes, or the Solution of certain Principles in Caloric, at the Temperature of the Atmoſphere.

CALORIC, in its combination with bodies, volatilizes ſome of them, and reduces them to the aëriform ſtate. The permanence in this ſtate in the temperature of the atmoſphere conſtitutes the gaſes ; ſo that, to reduce a ſubſtance to the ſtate of gas, conſiſts in diſſolving it in caloric.

Caloric combines with various bodies, with greater or leſs facility ; and we are acquainted with ſeveral that, at the temperature of the atmoſphere, are conſtantly in the ſtate of gas : there are others which paſs to this ſtate at ſome degrees higher, and theſe are called Volatile or Evaporable ſubſtances. They differ from fixed ſubſtances, becauſe theſe laſt are not volatilized but by the application and combination of a ſtrong doſe of caloric.

It appears that all bodies do not indiſcriminately require the ſame quantity of caloric to aſſume the gaſeous ſtate ; and we ſhall ſee that this

this proportion may be deduced from the fixation and concretion of these gaseous substances.

To reduce any substance to the state of gas, the application of caloric may be made in various manners.

The most simple method consists in placing the body in contact with another body which is heated. In this situation, the heat on one hand diminishes the affinity of aggregation or composition, by separating the constituent principles to a greater distance from each other; on the other hand, the heat unites to the principles with which it has the strongest affinity, and volatilizes them. This process is according to the method of simple affinities; for it in fact consists of the exhibition of a third body, which, presented to a compound of several principles, combines with one of them, and carries it off.

The method of double affinity may likewise be used to convert any substance into the gaseous form; and this is what happens when we cause one body to act upon another to produce a combination, in which a disengagement of some gaseous principles takes place. If I pour, for example, the sulphuric acid upon the oxide of manganese, the acid combines with the metal, while its caloric seizes the oxigene, and rises rifes with it. This principle takes place not only in this inftance, but on all other occafions wherein, an operation being performed without the application of heat, there is a production of vapour or gas.

The various ftates under which bodies prefent themfelves to our eyes, depend almoft entirely upon the different degrees of combination of caloric with thofe fame bodies. Fluids do not differ from folids, but becaufe they conftantly poffefs, at the temperature of the atmofphere, the dofe of caloric which is requifite to maintain them in that ftate; they congeal and pafs to the concrete ftate with greater or lefs facility, according as the requifite quantity of caloric is more or lefs confiderable.

All folid bodies are capable of paffing to the gafeous ftate; and the only difference which exifts between them in this refpect is, that a dofe of caloric is required for this purpofe, which is governed—1. By the affinity of aggregation, which connects their principles, retains them, and oppofes itfelf to a new combination. 2. By the weight of the conftituent parts, which renders their volatilization more or lefs difficult. 3. By the agreement and attraction between the caloric and the folid body, which is more or lefs ftrong.

All bodies, whether ſolid or liquid, when they come to be volatilized by heat, appear in two ſtates—that of vapour, or that of gas.

In the firſt caſe, theſe ſubſtances loſe, in a ſhort time, the caloric which raiſed them, and again appear in their original form the moment the caloric finds colder bodies to combine with; but it is rare that bodies thus divided reſume their original conſiſtence. The firſt ſtate is that of vapour.

In the ſecond caſe, the combination of caloric with the volatilized ſubſtance is ſuch, that the ordinary temperature of the atmoſphere is inſufficient to overcome this union. This ſtate conſtitutes the gaſes.

When the combination of caloric with any ſubſtance is ſuch that a gas is produced, theſe inviſible ſubſtances may be managed at pleaſure, by the aſſiſtance of apparatus appropriated within our time to theſe uſes. Theſe apparatus are known by the name of Pneumato-chemic, Hydro-pneumatic apparatus, &c.

The pneumato-chemical apparatus, in general, conſiſts of a wooden veſſel, uſually of a ſquare form, and lined with lead or tin: two or three inches beneath the upper edge there is formed a groove, in which a wooden plank ſlides, having a hole in the middle, and a notch in one of its ſides; the hole is made in the centre of an excavation made in the ſhelf, of the figure of a funnel.

This veſſel is filled with water or mercury, according to the nature of the gaſes operated upon. There are ſome which eaſily combine with water, and therefore require to be receiv-ed over mercury.

The gaſes may be extracted in various man-ners.

When they are diſengaged by fire, a recurv-ed tube is adapted to the neck of the retort, one extremity of which is plunged in the water or the mercury of the pneumato-chemical veſſel, and opens beneath the aperture in the ſhelf, which is in the form of a funnel. The junction of the tube with the neck of the re-tort is ſecured with the uſual lute; a veſſel fill-ed with the liquid of the ciſtern is inverted upon the ſhelf over the aperture. When the gas is diſengaged from the materials in the retort, it appears in the form of bubbles, which riſe, and gain the ſuperior part of the inverted veſſel. When all the water is diſplaced, and the bottle is full of gas, it is withdrawn, by adapting a glaſs plate to its orifice to prevent its diſſipa-tion: it may then be poured from one veſſel to another,

another, and ſubjected to a variety of experiments to aſcertain its nature.

When the gaſes are diſengaged by means of acids, the mixture which is deſigned to afford them is put into a bottle with a recurved tube fitted to its neck; and this tube is plunged in the ciſtern in ſuch a manner, that the bubbles of gas may paſs, as in the former experiment, through the aperture of the funnel in the ſhelf.

The proceſſes at preſent uſed to extract the gaſes, and to analyſe them, are ſimple and commodious; and theſe proceſſes have ſingularly contributed to our acquiſition of the knowledge of theſe aëriform ſubſtances, whoſe diſcovery has produced a revolution in chemiſtry.

CHAP. I.

Concerning Hydrogenous Gas, or inflammable Air.

INFLAMMABLE Air is one of the conſtituent parts of water; a circumſtance which has entitled it to the denomination of Hydrogenous Gas. Its property of burning with vital air has cauſed it to be diſtinguiſhed by the name of Inflammable Air.

Hydro-

Hydrogenous gas has been procured long ſince. The famous philoſophical candle atteſts the antiquity of this diſcovery; and the celebrated Hales obtained from moſt vegetables an air which took fire.

Hydrogenous gas may be extracted from all bodies in which it is a conſtituent part; but the pureſt is that afforded by the decompoſition of water, and it is this fluid which uſually affords it in our laboratories. For this purpoſe the ſulphuric acid is poured upon iron, or zinc; the water which ſerves as a vehicle for the acid, is decompoſed on the metal; its oxigene combines with it, while the hydrogenous gas eſcapes. This explanation, however contrary to the ancient notion, is not the leſs a demonſtrated truth; in fact, the metal exiſts in the ſtate of an oxide in its ſolution by the ſulphuric acid, as may be proved by precipitating it with pure vegetable alkali: on the other hand, the acid itſelf is not at all decompoſed; ſo that the oxigenous gas cannot have been afforded to the iron but by the water. Water may be decompoſed likewiſe ſtill more directly by throwing it upon iron ſtrongly heated; and hydrogenous gas may be obtained by cauſing water to paſs through a tube of iron ignited to whiteneſs.

The hydrogenous gas may be extracted by the

the ſimple diſtillation of vegetables. Vegetable fermentation, and animal putrefaction, likewiſe produce this gaſeous ſubſtance.

The properties of this gas are as follow:

A. Hydrogenous gas has a diſagreeable ſtinking odour. Mr. Kirwan has obſerved, that when it is extracted over mercury, it has ſcarcely any ſmell. It contains half its weight of water, and loſes its ſmell the moment it is deprived of this additional ſubſtance.

Kirwan has likewiſe obſerved, that the volume of hydrogenous gas is one-eighth larger when received over water than when received over mercury.

Theſe obſervations appear to prove, that the offenſive ſmell of this gas ariſes only from the water it holds in ſolution.

B. Hydrogenous gas is not proper for reſpiration. The abbé Fontana aſſures us that he could not take more than three inſpirations of this air: the count Morrozo has proved that animals periſh in it in a quarter of a minute. On the other hand, ſeveral northern chemiſts have affirmed, in conſequence of experiments made on themſelves, that hydrogenous gas might be reſpired without danger; and it is ſome years ſince the unfortunate Pilatre du Rozier filled his lungs with it at Paris, and ſet it on fire

fire during the expiration, which forms a very curious jet of flame. It was remarked to him, that the abbé Fontana had objected against the accuracy of the Swediſh chemiſts. This intrepid philoſopher anſwered the objection, by mixing one-ninth of atmoſpherical air with very pure hydrogenous gas. He reſpired this mixture, as uſual; but when he attempted to ſet it on fire, the conſequence was an exploſion ſo dreadful, that he imagined all his teeth were blown out.

This oppoſition of opinions and contradiction of experiments, reſpecting a phenomenon which ſeems capable of unanſwerable deciſion by one ſingle experiment, induced me to have recourſe to trial, to fix my own ideas on the ſubject.

Birds, ſucceſſively placed in a veſſel of hydrogenous gas, died, without producing the ſmalleſt perceptible change in the gas itſelf.

Frogs placed in forty inches of hydrogenous gas died in the ſpace of three hours and a half: while others lived fifty-five hours in oxigenous gas and atmoſpheric air; and when I took them out ſtill living, the air was neither vitiated nor diminiſhed. Numerous experiments which I have made upon theſe animals, have led me to obſerve that they have the faculty

culty of ſtopping their reſpiration, when placed in any noxious gas, to ſuch a degree, that they inſpire only once or twice, and afterwards ſuſpend every function on the part of the reſpiratory organ.

I have ſince had occaſion to obſerve that theſe animals are not reduced into a putrid maſs by remaining in hydrogenous gas, as was affirmed ſome time ago. The fact which may have impoſed on chemiſts who related this circumſtance, is, that frogs are often enveloped in a mucus or ſanies, which appears to cover them; but they exhibit the ſame phenomenon in all the gaſes.

After having tried the hydrogenous gas upon animals, I determined to reſpire it myſelf; and I found that the ſame volume of this air might be ſeveral times reſpired without danger. But I obſerved that this gas was not changed by theſe operations; whence I concluded that it is not reſpirable: for, if it were, it would ſuffer a change in the lungs, the object of reſpiration not being confined to the reception and emiſſion of a fluid merely; it is a function much more noble, more intereſting, more intimately connected with the animal œconomy: and we ought to conſider the lungs as an organ which is nouriſhed by the air, digeſts that which is preſented

ſented to it, retains the beneficial, and rejects the noxious part. Since therefore inflammable air can be reſpired ſeveral ſucceſſive times without danger to the individual, and without any alteration or change in itſelf, we may conclude indeed that inflammable air is not a poiſon, but that it cannot be conſidered as an air eſſentially proper to reſpiration. It is with hydrogenous gas in the lungs, as with thoſe balls of moſs and reſin which certain animals ſwallow during the rigorous ſeaſon of the winter. Theſe balls are not digeſted, ſince the animals void them at the return of ſpring: but they delude hunger; and the membranes of the ſtomach are exerciſed upon them without danger, in the ſame manner as the lungs exert themſelves upon the hydrogenous gas preſented to them.

C. Hydrogenous gas is not combuſtible alone; it does not burn but by the concurrence of oxigene. If a veſſel filled with this gas be reverſed, and a lighted taper be preſented to it, the hydrogenous gas is found to burn at the ſurface of the veſſel; but the candle is extinguiſhed the moment it is plunged lower. The moſt inflammable bodies, ſuch as phoſphorus, do not burn in an atmoſphere of hydrogenous gas.

D. Hydrogenous gas is lighter than common air.

air. One cubic foot of atmofpheric air weighs feven hundred and twenty grains; a cubic foot of hydrogenous gas weighs feventy-two grains. The barometer being at 29′ 9, and the thermometer 60° Fahrenheit, Mr. Kirwan found the weight of this air to that of common air as eighty-four to one thoufand; confequently it was about twelve times as light.

Its fpecific gravity varies very much, becaufe it is difficult to obtain it conftantly of the fame degree of purity. That which is extracted from vegetables contains the carbonic acid and oil, which increafes its weight.

This levity of hydrogenous gas has caufed certain philofophers to prefume that it ought to arrive at and occupy the fuperior part of our atmofphere; and upon this fuppofition the moft brilliant conjectures have been made refpecting the influence which a ftratum of this gas, predominating over the reft of the atmofphere, ought to produce in meteorology. They were not aware that this continual lofs of matter is not agreeable to the wife œconomy of nature. They did not obferve that this gas, during its afcent in the air, combines with other bodies, more efpecially the oxigene, and that water and other products are the refult; the knowledge of which muft muſt neceſſarily lead us to that of moſt meteors.

The theory of balloons, or aëroſtatic machines, is founded on this levity of the hydrogenous gas.

In order that a balloon may riſe in the atmoſphere, it is ſufficient that the weight of the balloon itſelf, and the air it encloſes, ſhould be leſs conſiderable than that of an equal bulk of atmoſpheric air; and it muſt riſe till its weight is in equilibrio with an equal volume of the ſurrounding air.

The theory of the Mongolfiers is every different from this. In this caſe a given volume of atmoſpheric air is rarefied by heat, and kept ſeparated from the common maſs by a hollow veſſel of cloth. This rarefied ſpace may therefore be conſidered for a moment as conſiſting of a maſs of air of greater levity, which muſt neceſſarily make an effort to riſe in the atmoſphere, and carry its covering along with it.

E. Hydrogenous gas exhibits various characters according to its degree of purity, and the nature of the ſubſtances which are mixed with it.

It ſeldom happens that this gas is pure. That which is afforded by vegetables contains oil, and the carbonic acid. The inflammable air of of marſhes is mixed with a greater or leſs quantity of carbonic acid; and that which is afforded by the decompoſition of pyrites ſometimes holds ſulphur in ſolution.

The colour of hydrogene, when ſet on fire, varies according to its mixtures. One-third of the air of the lungs, mixed with the inflammable air of pit-coal, affords a flame of a blue colour; inflammable air, mixed with nitrous air, affords a green colour; the vapour of ether affords a white flame. The various mixtures of theſe gaſes, and the degree of compreſſion to which they are ſubjected, when expreſſed out of an aperture in order to burn them, have, in the hands of certain operators, afforded very agreeable illuminations, well deſerving the attention of learned and curious obſervers.

F. Hydrogenous gas poſſeſſes the property of diſſolving ſulphur. In this caſe it contracts a ſtinking ſmell, and forms hepatic gas.

Mr. Gengembre put ſulphur into inverted veſſels filled with hydrogenous gas, and diſſolved it by means of the burning-glaſs. The hydrogenous gas, by this treatment, obtained all the characteriſtic properties of hepatic gas.

The formation of this gas is almoſt always an effect of the decompoſition of water. In fact, the alkaline ſulphures, or livers of ſulphur, do

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not emit any difagreeable fmell while they are dry; but the moment they are moiftened, an abominable fmell is perceived, and the fulphate of pot-afh, or vitriolated tartar, begins to be formed. Thefe phenomena prove that the water is decompofed; that one of its principles unites to the fulphur, and volatilizes it; while the other combines with the alkali, and forms a more fixed product.

Sulphurated hydrogenous gas may be obtained by diffolving the fulphures or hepars by acids. Thofe acids in which the oxigene is moft adherent difengage the greateft quantity. The muriatic acid produces twice as much as the fulphuric. That which is produced by this laft, burns with a blue flame; but that which is difengaged by the muriatic acid, burns with a yellowifh white flame.

Scheele has taught us the means of obtaining this gas in great abundance, by decompofing artificial pyrites, formed by three parts of iron and one of fulphur, to which fpirit of vitriol is added.

The natural decompofition of pyrites in the bowels of the earth produces this gas; which efcapes with certain waters, and communicates peculiar virtues to them.

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The moſt general properties of theſe gaſes are:

1. They render the white metals black.

2. They are improper for reſpiration.

3. They impart a green colour to ſyrup of violets.

4. They burn with a light blue flame, and depoſit ſulphur by this combuſtion.

5. They mix with the oxigenous gas of the atmoſpheric air, and form water; at the ſame time that the ſulphur, before held in ſolution, falls down. Hence it happens that ſulphur is found in the channels of hepatic waters, though their analyſis does not ſhew the exiſtence of an atom of that ſubſtance held in ſolution.

6. They impregnate water, and are ſparingly ſoluble in that fluid; but heat or agitation diſſipates them again.

The air which burns at the ſurface of certain ſprings, and forms what is known by the name of burning ſprings, conſiſts of hydrogenous gas holding phoſphorus in ſolution. It ſmells like putrid fiſh. The Pere Lampi has diſcovered one of theſe ſprings in the iſles of St. Colombat. Dauphiny exhibits another ſimilar ſpring at the diſtance of four leagues from Grenoble. The ignes fatui which glide along burying-

grounds,

grounds, and which the ſuperſtitious people ſuppoſe to conſiſt of the ſpirits of the departed, are phenomena of this nature, which we ſhall ſpeak of when we come to treat of phoſphorus.

CHAP. II.

Concerning Oxigenous Gas, or Vital Air.

THIS gaſeous ſubſtance was diſcovered by the celebrated Prieſtley, on the 1ſt of Auguſt 1774. Since that memorable day, means have been deviſed of obtaining it from various ſubſtances; and its properties have ſhewn that it is a production of the moſt intereſting nature in the knowledge of chemiſtry.

No part of the atmoſphere exhibits vital air in its greateſt degree of purity. It is always combined, mixed, or altered by other ſubſtances.

But this air, which is the moſt general agent in the operations of nature, exiſts in combination with various ſubſtances; and it is by their decompoſition that it may be extracted and procured.

A metal expoſed to the air becomes changed; and theſe changes are produced only by the combination of the pure air with the metal itſelf. Simple diſtillation of ſome of theſe metals thus changed, or oxides, is ſufficient to diſengage this vital air; and it is then obtained in a very pure ſtate, by receiving it in the hydro-pneumatic apparatus. One ounce of red precipitate affords about a pint.

All acids have vital air for their baſe: there are ſome which yield it eaſily. The diſtillation of nitre decompoſes the nitric acid; and about twelve hundred cubic inches of oxigenous gas are obtained from a pound of this ſalt.

The nitric acid, when diſtilled from various ſubſtances, is decompoſed, and its conſtituent parts may be obtained ſeparately.

Meſſrs. Prieſtley, Ingenhouſz, and Sennebier diſcovered nearly at the ſame time that vegetables expoſed to the light of the ſun emit vital air. We ſhall elſewhere ſpeak of the circumſtances of theſe phenomena; but ſhall at preſent confine ourſelves to the obſervation, that the emiſſion of vital air is proportioned to the vigour of the plant, and the vivacity of the light; and that the direct emiſſion of the rays of of the ſun is not neceſſary to produce this gaſeous dew; it is ſufficient that the plant be well enlightened, in order that it may tranſpire pure air: for I have often collected it in abundance from a kind of moſs which covers the bottom of a veſſel filled with water, and ſo well defended that the ſun never ſhone directly upon it.

In order to procure the vital air which is diſengaged from plants, it is ſufficient to encloſe them beneath a glaſs veſſel filled with water, and inverted over a tub filled with the ſame fluid. The moment the plant is acted on by the ſun, ſmall bubbles of air are formed on its leaves, which detaching themſelves riſe to the upper part of the veſſel, and diſplace the liquid.

This dew of vital air is a beneficial gift of nature to repair inceſſantly the conſumption of vital air. The plant abſorbs atmoſpherical mephitis, and emits vital air. Man, on the contrary, is kept alive by vital air, and emits much mephitis. It appears therefore that the animal and vegetable kingdoms labour for each other; and that by this admirable reciprocity of ſervices the atmoſphere is continually repaired, and an equilibrium maintained between its conſtituent principles.

The influence of ſolar light is not confined to the production of vital air by its action upon vegetables alone; it has likewise the singular property of decomposing certain substances, and disengaging this gas.

A bottle of oxigenated muriatic acid, exposed to the sun, suffers all the superabundant oxigene which it contained to escape, and passes to the state of ordinary muriatic acid. The same acid, exposed to the sun in a bottle wrapped in black paper, does not suffer any change; and, when heated in a dark place, is even reducible into gas without decomposition. The nitric acid likewise affords oxigenous gas, when exposed to the sun; whereas heat alone volatilizes it without decomposition.

The muriate, or marine salt of silver, placed under water, and exposed to the sun, suffers oxigenous gas to escape from it. I have observed that red precipitate likewise affords oxigene in similar cases, and that it becomes black in no very long space of time.

We may likewise obtain oxigenous gas by disengaging it from its bases by means of the sulphuric acid. The process to which I give the preference, on account of its simplicity, is the following:—I take a small apothecary's phial, into which I put one or two ounces of manganese, and pour thereon a sufficient quantity of sulphuric acid to form a liquid paste. I afterwards fit a cork to the opening of the bottle, with a hole through it, into which is inserted a recurved tube; one of whofe extremities enters the bottle, while the other is placed under the fhelf of the pneumato-chemical apparatus. When the apparatus is thus difpofed, I prefent a fmall coal to the lower part of the bottle, and oxigenous gas is immediately difengaged.

The manganefe I ufe was difcovered by me at St. Jean de Gardonnenque. It affords its oxigene with fuch facility, that nothing more is neceffary for this purpofe than to incorporate it with the fulphuric acid. This gas is not perceptibly mixed with nitrigenous gas (or phlogifticated air); and the firft bubble is as pure as the laft.

Oxigenous gas exhibits certain properties, according to its degree of purity. Thefe depend in general upon the fubftances which afford it. That which is obtained from the mercurial oxides almoft always holds a fmall quantity of mercury in folution: I have been a witnefs to its having produced a fpeedy falivation on two perfons who ufed it for diforders of the lungs. In confequence of thefe obfervations, I filled bottles with this gas, expofed them to an intenfe cold, and the fides became obfcured with a ftratum

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tum of mercurial oxide, in a ſtate of extreme diviſion. I have ſeveral times heated the bath, over which I cauſed this gas to paſs; and I obtained, at two different times, a yellow precipitate in the bottle in which I had received the gas.

The oxigenous gas extracted from plants is not equally pure with that afforded by the metallic oxides: but from whatever ſubſtances it is obtained, its general properties are the following:

A. It is more ponderous than the air of the atmoſphere; the cubic foot of atmoſpherical air weighing ſeven hundred and twenty grains, while the cubic foot of pure air weighs ſeven hundred and ſixty-five. According to Mr. Kirwan, its weight is to that of common air as eleven hundred and three to one thouſand. One hundred and ſixteen inches of this air weighed 39,09 grains; one hundred and ſixteen inches of common air weighed 35,38 grains at the temperature of ten degrees of Reaumur, and twenty-eight inches of preſſure. One hundred parts of common air weighed forty-ſix, and one hundred parts of vital air fifty.

B. Oxigenous gas is the only fluid proper for combuſtion. This acknowledged truth

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caufed the celebrated Scheele to give it the name of Air of Fire.

To proceed with greater order in the examination of one of the moft important properties of oxigenous gas, fince it belongs exclufively to this fluid, we fhall lay down the four following principles, as inconteftable refults of all the known facts.

The firft principle.—Combuftion never takes place without vital air.

The fecond principle.—In every combuftion there is an abforption of vital air.

The third principle.—There is an augmentation of weight in the products of combuftion equal to the weight of the vital air abforbed.

The fourth principle.—In all combuftion there is a difengagement of heat and light.

I. The firft of thefe propofitions is a ftrict truth. Hydrogenous gas does not burn alone, without the affiftance of oxigene; and all combuftion ceafes the moment that oxigenous gas is wanting.

II. The fecond principle contains a truth no lefs general. If certain bodies, fuch as phofphorus, fulphur, &c. be burned in very pure oxigenous gas, this is abforbed to the laft particle; and when the combuftion is effected in a mixture

mixture of ſeveral gaſes, the oxigene alone is abſorbed, and the others remain unchanged.

In the ſlower combuſtions, ſuch as the rancidity of oils, and the oxidation of metals, there is equally an abſorption of oxigene, as may be ſhewn by confining theſe bodies in a determinate maſs of air.

III. The third principle, though not leſs true than the preceding, requires more explanation; and for this purpoſe we ſhall diſtinguiſh thoſe combuſtions whoſe reſult, reſidue, and product are fixed, from thoſe which afford volatile and fugacious ſubſtances. In the firſt caſe the oxigenous gas quietly combines with the body; and by weighing the ſame body the moment the combuſtion has completely taken place, it is eaſily aſcertained whether the increaſe in weight be proportioned to the oxigene abſorbed. This happens in all the caſes wherein the metals are oxided, or oils rendered rancid; and in the production of certain acids, ſuch as the phoſphoric, the ſulphuric, &c. In the ſecond caſe, it is more difficult to weigh all the reſults of the combuſtion, and conſequently to aſcertain whether the augmentation in weight be proportioned to the quantity of the air abſorbed. Nevertheleſs, if the combuſtion be made in inverted veſſels, and the

the whole of the products be collected, it is found that their augmentation in weight is ſtrictly equal to that of the air abſorbed.

IV. The fourth principle is that whoſe applications are the moſt intereſting to be known.

In moſt combuſtions, the oxigenous gas becomes fixed and concrete. It therefore abandons the caloric which maintained it in the aëriform ſtate; and this caloric being ſet at liberty, produces heat, and endeavours to combine itſelf with the ſubſtances neareſt at hand.

The diſengagement of the heat is therefore a conſtant effect in all the caſes wherein vital air is fixed in bodies; and it follows, from this principle—1. That heat is moſt eminently reſident in the oxigenous gas which maintains combuſtion. 2. That the more oxigene is abſorbed in a given time, the ſtronger will be the heat. 3. That the only method of producing a violent heat conſiſts in burning bodies in the pureſt air. 4. That fire and heat muſt be more intenſe in proportion as the air is more condenſed. 5. That currents of air are neceſſary to maintain and expedite combuſtion. It is upon this principle that the theory of the effects of the cylinder lamps is founded: the current of air, which is renewed through the tube, ſupplies freſh air every inſtant; and by continually applying

plying a new quantity of oxigenous gas to the flame, a heat is produced ſufficient to ignite and deſtroy the ſmoke.

It is likewiſe on the ſame principle that we explain the great difference that exiſts between heat produced by a ſlow combuſtion, and that which is afforded by rapid combuſtion. In the latter caſe the ſame quantity of heat and light is produced in a ſecond, which might have been produced in the other caſe in a much longer time.

The phenomena of combuſtion, by means of oxigenous gas, depend likewiſe upon the ſame laws. Profeſſor Lichtenberger, of Gottingen, ſoldered the blade of a knife to a watch ſpring by means of oxigenous gas; Meſſrs. Lavoiſier and Erhmann have ſubjected almoſt all the known bodies to the action of fire maintained by oxigenous gas alone; and they produced effects which the burning-glaſs could not have operated.

Mr. Ingenhouſz has ſhewn us, that if an iron wire be bent into a ſpiral form, and any combuſtible ſubſtance whatever be fixed to one of its ends, and ſet on fire, the wire will itſelf be fuſed by plunging it into oxigenous gas.

Mr. Forſter, of Gottingen, found that the light of glow-worms is ſo beautiful and bright

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in oxigenous gas, that one ſingle inſect was ſufficient to afford light to read the Annonces Savantes of Gottingen, printed in a very ſmall character. Nothing more is wanting therefore than to apply this air to combuſtion with facility and œconomy; and Mr. Meuſnier has ſucceeded in this, by conſtructing a ſimple and commodious apparatus. On this ſubject the treatiſe of Mr. Erhmann upon fuſion may be conſulted.

The deſcription of the gazometer may likewiſe be ſeen in the Elementary Treatiſe of Chemiſtry, by Mr. Lavoiſier.

We ſhall diſtinguiſh three ſtates in the very act of combuſtion—ignition, inflammation, and detonation.

Ignition takes place when the combuſtible body is not in the aëriform ſtate, nor ſuſceptible of aſſuming that ſtate by the ſimple heat of combuſtion. This happens when well-made charcoal is burned.

When the combuſtible body is preſented to oxigenous gas, in the form of vapour or gas, the reſult is flame; and the flame is more conſiderable, in proportion as the combuſtible body is more volatile. The flame of a candle is not kept up but by the volatilization of the wax, which is continually effected by the heat of the combuſtion.

Deto-

Detonation is a ſpeedy and rapid inflammation, which occaſions a noiſe by the inſtantaneous formation of a vacuum. Moſt detonations are produced by the mixture of hydrogenous and oxigenous gas, as I have ſhewn in my Memoir upon Detonations, in the year 1781, It has been ſince proved, that the product of the rapid combuſtion of theſe two gaſes is water. Very ſtrong detonations may be produced by burning a mixture of one part of oxigenous gas with two of hydrogene. The effect may be rendered ſtill more terrible, by cauſing the mixture to paſs through ſoap-water, and ſetting fire to the bubbles which are heaped on the ſurface of the fluid.

Chemiſtry preſents ſeveral caſes in which the detonation ariſes from the ſudden formation of ſome gaſeous ſubſtances, ſuch as that which is produced by the inflammation of gunpowder; for in this caſe there is a ſudden production of carbonic acid, of nitrogene gas, &c. The production or inſtantaneous creation of any gas whatever, muſt occaſion a ſhock or agitation in the atmoſphere, which neceſſarily affords an exploſion; the effect of theſe exploſions increaſes, and becomes ſtronger, from the oppoſition of any obſtacles againſt the eſcape of the gas.

C. Oxigenous gas is the only gas proper for reſpira-

reſpiration. It is this moſt eminent property which has entitled it to the name of Vital Air; and we ſhall give the preference to this denomination in the preſent article.

It has long ſince been known that animals cannot live without the aſſiſtance of air. But the phenomena of reſpiration have been very imperfectly known until lately.

Of all the authors who have written concerning reſpiration, the ancients are thoſe who have had the moſt accurate ideas of it. They admitted in the air a principle proper to nouriſh and ſupport life, which they denoted by the name of *pabulum vitæ*; and Hippocrates expreſsly ſays, *ſpiritus etiam alimentum eſt.* This idea, which was connected with no hypotheſis, has been ſucceſſively replaced by ſyſtems void of all foundation. Sometimes the air has been conſidered as a ſtimulus in the lungs, which kept up the circulation by its continual action. Vide Haller.—Sometimes the lungs have been conſidered as bellows deſigned to cool the body, heated by a thouſand imaginary cauſes: and when it was proved that the volume of air was diminiſhed in the lungs, it was thought to be an explanation of every difficulty, to ſay that the air was deprived of its ſpring.

At this day, however, we are enabled to throw

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ſome light on one of the moſt important functions of the human body. In order to proceed with more perſpicuity, we ſhall reduce our notions to ſeveral principles.

1. No animal can live without the aſſiſtance of air. This fact is univerſally admitted; but it has not been known until lately that the faculty which the air poſſeſſes of anſwering the purpoſe of reſpiration, ariſes only from one of the principles of atmoſpheric air, known by the name of vital air.

2. All animals do not require the ſame purity in the air. Birds, as well as men, and the greateſt part of quadrupeds, require a very pure air; but thoſe which live in the earth, or which hide themſelves in a ſtate of ſtupefaction during the winter, can ſubſiſt by means of a leſs pure air.

3. The manner of reſpiring the air is different in the ſeveral ſubjects. In general, nature has given to animals an organ, which by its involuntary dilatation and contraction receives and expels the fluid in which the animal moves and exiſts. This organ is more or leſs perfect, more or leſs concealed and defended from external injury, according to its importance, and influence upon the life of the creature, as Mr. Brouſſonnet has obſerved.

Amphi-

Amphibious animals reſpire by means of lungs: but they can ſuſpend their motion even whilſt they are in the air; as I have obſerved with regard to frogs, which ſtop their reſpiration at pleaſure.

The manner of reſpiration in fiſhes is very different; theſe animals come from time to time to inhale the air at the ſurface of the water, where they fill their veſicle, and digeſt it afterwards at their eaſe. I have for a long time obſerved the phenomena of fiſhes in the act of reſpiration; and am well aſſured that they are ſenſible of the action of all the gaſes, like other animals. Mr. De Fourcroy has obſerved that the air contained in the veſicle of the carp is nitrogene gas (phlogiſticated air).

Inſects with tracheæ exhibit organs ſtill more remote from ours in their conſtruction. In theſe animals, reſpiration is effected by the tracheæ diſtributed along the body. They accompany all the veſſels, and terminate by loſing themſelves in inſenſible pores at the ſurface of the ſkin.

Theſe inſects appear to me to exhibit ſeveral very evident points of analogy with vegetables.

1. Their reſpiratory organs are formed in the ſame manner, being diſpoſed through the whole body of the vegetable and the animal.—

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2. Insects do not require a great degree of purity in the air; and plants are nourished with atmospherical mephitis.—3. Both the one and the other transpire vital air. The abbé Fontana discovered several insects in stagnant waters, which, when exposed to the sun, afforded vital air: and the green matter which is formed in stagnant waters, and is by Dr. Priestley placed among the confervæ, in conformity with the opinion of his friend Mr. Bewley—which Mr. Senebier has supposed to be the *conferva cespitosa filis rectis undique divergentibus Halleri*, and which has appeared to Dr. Ingenhousz to be nothing else but a mass of animalcula—affords a prodigious quantity of this air when exposed to the sun.—4. Insects likewise afford, by chemical analysis, principles similar to those of plants, such as resins, volatile oils, &c.

Father Vaniere appears to have known, and very elegantly expressed, the property of vegetables to support themselves by means of vital air:

. . . Arbor enim (res non ignota), ferarum
Instat et halituum, piscisque latentis in imo
Gurgite, vitales et reddit et accipit auras.

Proedium Rusticum, l. vi.

Animals with lungs respire only by virtue of the vital air which surrounds them. Any gas deprived

deprived of this mixture becomes immediately improper for refpiration: and this function is exercifed with fo much the greater liberty, as vital air exifts in a greater proportion in the air refpired.

Count Morozzo placed fucceffively feveral full-grown fparrows under a glafs bell, inverted over water. It was at firft filled with atmofpherical air, and afterwards with vital air. He obferved—

1. In atmofpherical air,

	Hours.	Min.
The firft fparrow lived	3	0
The fecond -	0	3
The third - -	0	1

The water rofe in the veffel eight lines during the life of the firft; four during the life of the fecond; and the third produced no abforption.

2. In vital air,

	Hours.	Min.
The firft fparrow lived	5	23
The fecond - -	2	10
The third - -	1	30
The fourth - -	1	10
The fifth - -	0	30
The fixth - -	0	47
The feventh - -	0	27
The eighth - -	0	30
The ninth - -	0	22
The tenth - -	0	21

From theſe experiments it may be concluded, 1. That an animal lives longer in vital air than in atmoſpherical-air. 2. That an animal can live in air in which another has died. 3. That, independent of the nature of the air, reſpect muſt be had to the conſtitution of the animals, as the ſixth lived forty-ſeven minutes, and the fifth only thirty. 4. That there is either an abſorption of air, or the production of a new kind of air, which is abſorbed by the water as it riſes.

It remains, at preſent, to examine what are the changes produced by reſpiration. 1. In the air. 2. In the blood.

The gas emitted by expiration is a mixture of nitrogene gas, carbonic acid, and vital air. If the air which iſſues from the lungs be made to paſs through lime-water, it renders it turbid; if it be received through tincture of turnſole, it reddens it; and if a pure alkali be ſubſtituted inſtead of the tincture of turnſole, it becomes effervescent.

When the carbonic acid has been abſorbed by the foregoing proceſs, the remainder of this air conſiſts of nitrogene gas and vital air. The vital air is ſhewn to be preſent by means of nitrous air. The air in which I had cauſed five ſparrows to periſh, afforded ſeventeen hundredth parts of vital air. After having thus deprived

the

the expired air of all its vital air, and all its carbonic acid, the remainder is nitrogene gas.

It has been obſerved that frugivorous animals vitiate the air leſs than carnivorous animals.

A portion of the air is abſorbed in reſpiration. Borelli formerly took notice of this; and Dr. Jurin had calculated that a man inſpired forty cubic inches of air in his uſual inhalations, and that in the greateſt he could receive two hundred and twenty inches; but that a portion was always abſorbed. The celebrated Dr. Hales endeavoured to determine this abſorption more ſtrictly, and he eſtimated it at a ſixty-eighth of the total of the reſpired air; but he did not conſider it as more than a hundred and thirty-ſixth, on account of errors which he ſuppoſed to have taken place. Now a man reſpires twenty times in a minute, and inhales forty cubic inches of air at each inſpiration; this makes forty-eight thouſand per hour; which, divided by one hundred and thirty-ſix, gives about three hundred and fifty-three inches of air abſorbed and deſtroyed in the hour. The proceſs of Hales is not exact; becauſe he paſſed the air expired through water, which muſt have retained a ſenſible proportion.

From more accurate experiments, Mr. De la

Metherie has proved, that three hundred and ſixty cubic inches of vital air are abſorbed in an hour.

My experiments have not ſhewn near ſo great a loſs.

This fact affords a proof of the facility with which air is vitiated by reſpiration when it is not renewed, and ſhews why the air of theatres is in general ſo unwholeſome.

II. The firſt effect which the air appears to produce upon the blood is, that of giving it a vermilion-colour. If the blackiſh venous blood be expoſed in a pure atmoſphere, it becomes of a vermilion-colour at its ſurface: this fact is daily obſerved when blood is ſuffered to remain expoſed in a porringer to the air. Air which has remained in contact with blood, extinguiſhes candles, and precipitates lime-water. Air injected into a determinate portion of a vein between two ligatures, renders the blood of a higher colour, according to the fine experiments of Dr. Hewſon.

The blood which returns from the lungs is of a higher colour, according to the obſervations of Meſſrs. Cigna, Hewſon, &c. Hence ariſes the great intenſity of the colour of arterial blood, compared with venous blood.

Mr. Thouvenel has proved, that by withdrawing

drawing the air which is in contact with the blood, it may be again made to lose its colour.

Mr. Beccaria exposed blood in a vacuum, where it remained black, but assumed the most beautiful vermilion-colour as soon as it was again exposed to the air. Mr. Cigna covered blood with oil, and it preserved its black colour.

Dr. Priestley caused the blood of a sheep to pass successively into vital air, common air, mephitic air, &c. and he found that the blackest parts assumed a red colour in respirable air, and that the intensity of this colour was in proportion to the quantity of vital air present. The same philosopher filled a bladder with blood, and exposed it to pure air. That portion of blood which touched the surface of the bladder, became red, while the internal part remained black; an absorption of air therefore took place through the bladder, in the same manner as when the contact is immediate.

All these facts incontestably prove, that the vermilion-colour assumed by the blood in the lungs, is owing to the pure air which combines with it.

The vermilion-colour of blood is therefore the first effect of the contact, absorption, and combination of pure air with the blood.

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The ſecond effect of reſpiration is to eſtabliſh a real focus of heat in the lungs; which is a circumſtance very oppoſite to the precarious and ridiculous notion of thoſe who have conſidered the lungs as a kind of bellows deſigned to cool the human body.

Two celebrated phyſicians, Hales and Boerhaave, have obſerved that the blood acquired heat in paſſing through the lungs; and modern phyſiologiſts have eſtimated this augmentation of heat at eleven hundredths.

The heat in each claſs of individual animals is proportioned to the magnitude of their lungs, according to Meſſrs. De Buffon and Brouſſonnet.

Animals with cold blood have only one auricle and one ventricle, as Ariſtotle obſerved.

Perſons who have reſpired vital air, agree in affirming that they perceived a gentle heat vivifying the lungs, and inſenſibly extending from the breaſt into all other parts of the body.

Ancient and modern facts unite therefore to prove, that a focus of heat really exiſts in the lungs; and that it is maintained and kept up by the air of reſpiration. We are able, at preſent, to explain all theſe phenomena. In fact, there is an abſorption of vital air in reſpiration. Reſpiration then may be conſidered as an operation

tion by means of which vital air paſſes continually from the gaſeous to the concrete ſtate; it muſt therefore at each inſtant abandon the heat which held it in ſolution, and in the ſtate of gas. This heat produced at every inſpiration muſt be proportioned to the volume of the lungs, to the activity of this organ, to the purity of the air, the rapidity of the inſpirations, &c. Hence it follows that during the winter, the heat produced muſt be more conſiderable, becauſe the air is more condenſed, and exhibits more vital air under the ſame volume. By the ſame reaſon, reſpiration ought to produce more heat in the inhabitants of northern climates; and this is one of the cauſes prepared by nature to temperate, and continually balance, the extreme cold of theſe climates. It follows likewiſe that the lungs of aſthmatic perſons are leſs capable of digeſting the air; and I am aſſured that they emit the air without vitiating it; from which cauſe their complexion is cold, and their lungs continually languiſhing; vital air is therefore wonderfully comfortable to them. It may be eaſily conceived from theſe principles why the heat of animals is proportioned to the volume of their lungs; and why thoſe which have only one auricle, and one ventricle, have cold blood, &c.

The

The phenomena of reſpiration are therefore the ſame as thoſe of combuſtion.

Vital air, by combining with the blood, forms the carbonic acid, which may be conſidered as antiputreſcent as long as it remains in the circulation; and that it is afterwards emitted through the pores of the ſkin, according to the experiments of the count De Milly, and the obſervations of Mr. Fouquet.

Vital air has been uſed with ſucceſs in certain diſorders of the human body. The obſervations of Mr. Caillens are well known. He cauſed perſons affected with phthiſical diſorders to reſpire it with the greateſt ſucceſs. I have myſelf been a witneſs to the moſt wonderful effects of this air in a ſimilar caſe. Mr. De B—— was in the laſt ſtage of a confirmed phthiſis. Extreme weakneſs, profuſe ſweats, a flux of the belly, and in ſhort every ſymptom, announced the approach of death. One of my friends, Mr. De P——, put him upon a courſe of vital air. The patient reſpired it with delight, and aſked for it with all the eagerneſs of an infant at the breaſt. During the time that he reſpired it he felt a comfortable heat, which diſtributed itſelf through all his limbs. His ſtrength increaſed with the greateſt rapidity; and in ſix weeks he was able to take long walks.

This

This ſtate of health laſted for ſix months: but after this interval he relapſed; and being no longer able to have recourſe to the uſe of vital air, becauſe Mr. De P—— had departed for Paris, he died.—I am very far from being of opinion that the reſpiration of vital air ought to be conſidered as a ſpecific, in caſes of this nature. I am even in doubt whether this powerful air is perfectly adapted to ſuch circumſtances; but it inſpires cheerfulneſs, renders the patient happy, and in deſperate caſes it is moſt certainly a precious remedy, which can ſpread flowers on the borders of the tomb, and prepare us in the gentleſt manner for the laſt dreadful effort of nature.

The abſolute neceſſity of vital air in reſpiration, enables us to lay down poſitive principles for purifying the corrupted air of any given place. This may be done in three ways. The firſt conſiſts in correcting the vitiated air by means of ſubſtances which are capable of ſeizing the noxious principles. The ſecond conſiſts in diſplacing the corrupted air, and ſubſtituting freſh air in the room of it; as is done by means of ventilators, the agitation of doors, &c. And the third conſiſts in pouring into the mephitiſed atmoſphere a new quantity of vital air.

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The proceſſes employed in purifying corrupted air, are not all certain in their effects. The fires which are lighted for this purpoſe have no other advantage than to eſtabliſh aſcending currents, and to burn unhealthy exhalations; and perfumes do nothing more than diſguiſe the bad ſmell, without changing the nature of the air, as the experiments of Mr. Achard ſhew.

CHAP. III.

Concerning Nitrogene Gas, Azote, or Atmoſpherical Mephitis.

IT has been long ſince aſcertained, that air which has ſerved the purpoſes of combuſtion and reſpiration, is no longer proper for thoſe uſes; the air thus corrupted has been diſtinguiſhed by the names of Phlogiſticated Air, Mephitiſed Air, Atmoſpherical Mephitis, &c. I call it Nitrogene Gas, for the reaſons explained in the Preliminary Diſcourſe.

But this reſidue of combuſtion or reſpiration is always mixed with a ſmall quantity of vital air and carbonic acid, which muſt be removed in order to have the nitrogene gas in a ſtate of purity. There are ſeveral methods which

may

may be uſed to obtain nitrogene gas, in a very pure ſtate.

1. Scheele has taught us, that by expoſing ſulphure of alkali, or liver of ſulphur, in a veſſel filled with atmoſpherical air, the vital air is abſorbed; and, when the abſorption is complete, the nitrogene gas remains pure.

By expoſing, in atmoſpheric air over mercury, a mixture of iron and ſulphur, kneaded together with water, Mr. Kirwan obtained nitrogene gas ſo pure, that it ſuffered no diminution by nitrous gas. He deprived it of all humidity, by ſucceſſively introducing dried blotting-paper into the veſſel which contained it. Care muſt be taken to withdraw this air in time from the paſte which affords it; otherwiſe it will be mixed with hydrogene or inflammable gas, which is afterwards diſengaged. 2. When by any means, ſuch as the oxidation of metals, the rancidity of oils, the combuſtion of phoſphorus, &c. the vital air of the atmoſphere is abſorbed, the reſidue is nitrogene gas. All theſe proceſſes afford methods of greater or leſs accuracy to determine the proportions of vital air and nitrogene gas in the compoſition of the atmoſphere.

3. This mephitis may likewiſe be procured by treating muſcular fleſh, or the well-waſhed fibrous part of blood, with nitric acid in the

hydro-

hydro-pneumatic apparatus. But it muſt be carefully obſerved that theſe animal matters ought to be freſh; for, if they have begun to be changed by the putrid fermentation, they afford carbonic acid mixed with hydrogene gas.

A. This gas is improper for reſpiration and combuſtion.

B. Plants live in this air, and freely vegetate in it.

C. This gas mixes with the other airs, without combining with them.

D. It is lighter than the atmoſpheric air, the barometer ſtanding at 30.46, and Fahrenheit's thermometer at 60: the weight of nitrogene gas is to that of common air as nine hundred and eighty-five to one thouſand.

E. Mixed with vital air, in the proportion of 72 to 28, it conſtitutes our atmoſphere. The other principles which analyſis exhibits in the atmoſphere, are only accidental, and by no means neceſſary.

SEC.

SECTION VI.

Concerning the Mixture of Nitrogene and Oxigene Gas; or of Atmoſpheric Air.

THE gaſeous ſubſtances we have treated of ſeldom exiſt alone and inſulated; nature preſents them every where to our obſervation in a ſtate of mixture or of combination. In the firſt caſe theſe gaſes preſerve the aëriform ſtate; in the ſecond they for the moſt part form fixed and ſolid bodies. Nature, in its ſeveral decompoſitions, reduces almoſt all the principles of bodies into gas. Theſe new ſubſtances unite together, combine, and from thence reſult compounds of conſiderable ſimplicity in their principles, but which become complicated by ſubſequent mixture and combinations. We may follow the operations of nature, ſtep by ſtep, without departing from the plan we have adopted.

The mixture of about ſeventy-two parts of nitrogene gas, and twenty-eight of oxigene, forms this fluid maſs in which we live. Theſe two principles are ſo well mixed, and each of them is ſo neceſſary to the ſupport of the various functions of individuals which live or

vegetate

vegetate upon the globe, that they have not yet been found feparate and alone.

The proportion of thefe two gafes is fubject to variation in the mixture which forms the atmofphere: but this difference depends only upon local caufes: and the moft ufual proportion is that which we have here mentioned.

The characteriftic properties of vital air are modified by thofe of nitrogene gas, and thefe modifications even feem to be neceffary; for if we were to refpire vital air in its ftate of purity, it would quickly confume our life; and this virgin air is no more fuitable to our exiftence than diftilled water. Nature does not appear to have defigned us for the ufe of thefe principles in their greateft degree of perfection.

The atmofpheric air is elevated feveral leagues above our heads, and fills the deepeft fubterraneous cavities. It is invifible, infipid, inodorous, ponderous, elaftic, &c. It was the only gafeous fubftance known before the prefent epocha of chemiftry; and the infinite gradations of all the invifible fluids which prefented themfeves fo frequently to the obfervation of philofophers, were always attributed to modifications of the air. Almoft the whole of what has been written upon the air relates only

to

to its phyſical properties. We ſhall confine ourſelves to point out the chief of theſe.

A. Air is a fluid of extreme rarefaction, obedient to the ſmalleſt motion: the ſlighteſt percuſſion deranges it; and its equilibrium, which is continually deſtroyed, is continually endeavouring to reſtore itſelf.

Though very fluid, it paſſes with difficulty through orifices by means of which groſſer liquids can eaſily penetrate. This has cauſed philoſophers to ſuppoſe that its parts were of a branched form *.

B. The atmoſpheric air is inviſible. It refracts the rays of light without reflecting them: for it is without ſufficient proofs that ſome philoſophers have imagined that large maſſes of this fluid are of a blue colour.

It appears that the air is inodorous itſelf; though it is the vehicle of odorant particles.

It may be conſidered as inſipid; and when its contact affects us variouſly, we ought to attribute it to its phyſical qualities.

C. It was not until the middle of the laſt century

* This is a deception. It is true that the coheſive attraction renders it difficult to diſplace any denſe fluid from a capillary tube by the intruſion of air; but every experiment of the air-pump, the condenſor, and the barometer, ſhews with what facility the air paſſes through the ſmalleſt orifices. T.

century that its weight was afcertained by accurate experiments. The impoffibility of fupporting water in a tube open at the bottom, to a greater height than thirty-two feet, caufed Torricellius to fufpect that an external caufe fupported the liquid at that height, and that it was not the horror of a vacuum which precipitated the water in the barrels of pumps. This celebrated philofopher filled a tube clofed at one of its extremities with mercury; he reverfed this into a veffel filled with the fame metal; and obferved that the mercury, after feveral ofcillations, conftantly fubfided to the height of twenty-eight inches. He immediately faw that the difference of elevations correfponded with the relative weights of thefe two fluids, which are in the proportion of fourteen to one. The immortal Pafchal proved, fome time afterwards, that liquids were fupported at this elevation by a column of atmofpherical air; and afcertained that their height varies according to the length of the column which preffes upon them.

D. The elafticity of the air is one of the properties upon which natural philofophers have made the greateft number of experiments; and it has even been applied to confiderable advantage in the arts.

SEC-

SECTION VII.

Concerning the Combination of Oxigenous Gas and Hydrogene, which forms Water.

WATER has been long confidered as an elementary principle; and when accurate experiments had compelled chemifts to clafs it among compound fubftances, a refiftance and oppofition were made to it, which were not manifefted when the air, the earth, and the other matters reputed to be elementary, were fubjected to fimilar revolutions. It feems to me, however, that this analyfis is equally ftrict with that of the air. Water is decompofed by feveral proceffes; it is formed by the combination of oxigene and hydrogene: and we find that all the phenomena of nature and art confpire to prove the fame truth. What more can be required to afford an abfolute certainty refpecting any phyfical fact?

Water is contained in bodies in a greater or lefs quantity, and may be confidered in two ſtates: it is either in the ſtate of ſimple mixture, or in a ſtate of combination. In the firſt caſe, it renders bodies humid, is perceptible to the eye, and may be diſengaged with the greateſt facility. In the ſecond, it exhibits no character which ſhews that it is in a ſtate of mixture. It exiſts in this form in cryſtals, ſalts, plants, animals, &c. It is this water which the celebrated Bernard has called Generative Water; and of which he has made a fifth element, to diſtinguiſh it from exhalative water.

Water, exiſting in a ſtate of combination in bodies, concurs in imparting to them hardneſs and tranſparency. Salts, and moſt ſtony cryſtals, loſe their tranſparency when they are deprived of their water of cryſtallization.

Some bodies are indebted to water for their fixity. The acids, for example, acquire fixity only by combining with water.

Under theſe various points of view, water may be conſidered as the general cement of nature. The ſtones and ſalts which are deprived of it, become pulverulent; and water facilitates the coagulation, re-union, and conſiſtence of the particles of ſtones, ſalts, &c. as we ſhall ſee in the operations performed with plaſters, lutes, mortar, &c.

Water, when diſengaged from its combinations,

tions, and in a ſtate of abſolute liberty, is one of the moſt conſiderable agents in the operations of this globe. It bears a part in the formation and decompoſition of all the bodies of the mineral kingdom: it is neceſſary to vegetation, and to the free exerciſe of moſt of the functions of animal bodies; and it haſtens and facilitates the deſtruction of theſe bodies, as ſoon as they are deprived of the principle of life.

For a certain time water was thought to be a fluid earth. The diſtillation, trituration, and putrefaction of water, which always left an earthy reſidue, afforded credit to an opinion that it was converted into earth. On this ſubject, the works of Wallerius and Margraff may be conſulted: but Mr. Lavoiſier has ſhewn that this earth ariſes from the wear of the veſſels; and the celebrated Scheele has proved the identity of the nature of this earth with that of the glaſs veſſels in which the operations were made. So that the opinions of the philoſophical world are at preſent decided in this reſpect.

In order to obtain accurate ideas of a ſubſtance ſo neceſſary to be known, we will conſider water under its three different ſtates of ſolidity, fluidity, and gas.

ARTICLE I.

Concerning Water in the State of Ice.

Ice is the natural ſtate of water, whenever it is deprived of a portion of that caloric with which it is combined when it appears in the form of a liquid or gas.

The converſion into ice is attended with ſeveral phenomena which ſeldom vary.

A. The firſt of all, and at the ſame time the moſt extraordinary, is a ſenſible production of heat at the moment in which the water paſſes to the ſolid ſtate. The experiments of Meſſrs. Fahrenheit, Treiwald, Baumé, De Ratte, leave no doubt on this ſubject; ſo that the water is colder at the inſtant of congelation than the ice itſelf.

A ſlight agitation of the fluid facilitates its converſion into ice, nearly in the ſame manner as the ſlighteſt motion very frequently determines the cryſtallization of certain ſalts. This ariſes, perhaps, from the circumſtance, that by this means the caloric, which is interpoſed between the particles, and may oppoſe itſelf to the production of the phenomenon, may be expreſſed

expreſſed or diſengaged. In proof of this opinion, it is ſeen that the thermometer riſes at the very ſame inſtant, according to Fahrenheit.

B. Frozen water occupies a larger ſpace than fluid water: we are indebted to the Academy del Cimento for the proofs of this truth. In their experiments, bomb ſhells, and the ſtrongeſt veſſels, being filled with water, were burſt into pieces by the congelation of this fluid. The trunks of trees are divided and ſplit with a loud noiſe, as ſoon as the ſap freezes; and ſo likewiſe ſtones are broken in pieces the moment the water with which they are impregnated paſſes to the ſtate of ice.

C. Ice appears to be nothing more than a confuſed cryſtallization. Mr. De Mairan obſerved that the needle-formed cryſtals of ice unite in an angle of either ſixty or one hundred and twenty degrees.

Mr. Pelletier obſerved, in a piece of fiſtulous ice, cryſtals in the form of flattened triangular priſms, terminated by two dehedral ſummits.

Mr. Sage obſerves, that if a piece of ice, which contains water in its internal parts, be broken, the water runs out, and the internal cavity is found to be lined with beautiful tetrahedral priſms, terminated in four-ſided priſms. Theſe priſms are often articulated and croſſed.

Vide

Vide M. Sage, Annales de Chimie, tom. i. p. 77.

Mr. Macquart has obſerved, that when it ſnows at Moſcow, and the atmoſphere is not too dry, the air is obſerved to be loaded with beautiful cryſtallizations regularly flattened, and as thin as a leaf of paper. They conſiſt of an union of fibres which ſhoot from the ſame centre to form ſix principal rays, and theſe rays divide themſelves into ſmall blades extremely brilliant: he obſerved ſeveral of theſe flattened radii which were ten lines in diameter.

D. When water paſſes from the ſolid to the liquid ſtate, it produces cold by the abſorption of a portion of heat, as is confirmed by the fine experiments of Wilcke. This production of cold, by the fuſion of ice, is likewiſe proved by the practice of the confectioners, who fuſe certain ſalts with ice, in order to produce a degree of cold below o.

Ice is found in many places in great maſſes, known by the name of Glacieres; certain mountains are conſtantly covered with them, and the ſouthern ocean abounds with them. The ice formed by ſalt water affords freſh water when melted; and in ſeveral northern provinces water is ſaid to be concentrated by froſt, to collect the ſalt it holds in ſolution. I have likewiſe obſerved,

obſerved, that ſeveral metallic ſalts are precipitated by expoſing their ſolutions to a temperature ſufficient to freeze them. The ice which was formed did not poſſeſs the characters of the ſalt which had been diſſolved.

Hail and ſnow are nothing but modifications of ice. We may conſider hail as produced by the ſudden diſengagement of the elaſtic fluid, which concurs in rendering water liquid: it is almoſt always accompanied with thunder. The experiments of Mr. Quinquet have confirmed this theory.—I will here relate a fact to which I myſelf was witneſs, at Montpelier, and of which philoſophers may advantageouſly avail themſelves. On the 29th of October, 1786, four inches of water fell at Montpelier; a violent exploſion of thunder, which was heard about four in the evening, and which appeared to be very near, cauſed a moſt dreadful ſhower of hail. At this inſtant a druggiſt, who was employed in his cellar in preventing the miſchief occaſioned by the filtration of water through the wall, was highly aſtoniſhed to behold that the water which came through the wall was inſtantly changed into ice. He called in ſeveral neighbours to partake of his ſurpriſe. I viſited the place a quarter of an hour afterwards, and found ten pounds of ice at the foot of the wall; I was

well

well aſſured that it could not have paſſed through the wall, which did not exhibit any crack, but appeared to be in very good condition. Did the ſame cauſe, which determined the formation of hail in the atmoſphere, act equally in this cellar?—I relate the fact only, and forbear to make any conjecture upon it.

ARTICLE II.

Concerning Water in the Liquid State.

The natural ſtate of water appears to be that of ice: but its moſt uſual ſtate is that of fluidity; and under this form it poſſeſſes certain general properties, which we ſhall proceed to deſcribe.

The experiments of the Academy del Cimento have cauſed the philoſophical world to deny the leaſt elaſticity to water, becauſe it eſcaped through the pores of balls of metal ſtrongly compreſſed, rather than yield to preſſure. But Meſſrs. Zimmerman, and the abbé Mongez, have endeavoured to prove its elaſticity from the very experiments upon which the contrary opinion has been built *.

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* The experiments of Canton, to prove the compreſſibility of water, are well known, and may be ſeen in the Philoſophical

The liquid ſtate renders the force of aggregation in water leſs powerful, and it enters into combination more readily in this form. Water which flows on the ſurface of our globe is never pure. Rain-water is ſeldom exempt from ſome mixture, as appears from the fine ſeries of experiments of the celebrated Margraff. I have aſcertained, at Montpelier, that the rain-water in ſtorms is more impure than that of a gentle ſhower—that the water which falls firſt is leſs pure than that which falls after ſeveral hours or ſeveral days rain—that the water which falls when the wind blows from the ſea to the ſouthward, contains ſea-ſalt ; whereas that which is produced by a northerly wind, does not contain a particle.

Hippocrates has made ſeveral very important obſervations reſpecting the various qualities of water, relative to the nature of the ſoil, the temperature of the climate, &c.

As it is of importance to the chemiſt to have very pure water for ſeveral delicate operations,

phical Tranſactions. He encloſed water in ſpherical glaſs veſſels, from which a narrow neck proceeded, like that of a thermometer : the water was found to occupy a larger ſpace when the preſſure of the atmoſphere was removed by the air-pump, and a leſs ſpace when a greater preſſure was added by the condenſor. T.

it is neceſſary to point out the means which may be uſed to carry any water whatever to this degree of purity.

Water is purified by diſtillation. This operation is performed in veſſels called Alembics. The alembic is compoſed of two pieces; a boiler or cucurbit, and a covering called the capital or head.

The water is put into the cucurbit, from which it is raiſed in vapours by means of fire, and theſe vapours are condenſed by cooling the head with cold water. The condenſed vapours flow into a veſſel deſigned to receive them. This is called Diſtilled Water; and is pure, becauſe it has left behind it in the cucurbit the ſalts and other fixed principles which altered its purity.

Diſtillation is more ſpeedy and quick, in proportion as the preſſure of the air is leſs upon the ſurface of the ſtagnant fluid. Mr. Lavoiſier diſtilled mercury *in vacuo;* and the abbé Rochon has made a happy application of theſe principles to diſtillation. It is to this ſame principle that we muſt refer the obſervations of almoſt all naturaliſts and philoſophers, who have remarked, that the ebullition in the liquid becomes more eaſy, in proportion as we aſcend a mountain from any other elevation; and it is in in conſequence of theſe principles, that Mr. Achard conſtructed an inſtrument to determine the heights of mountains, by the degrees of temperature of the ebullition of boiling water.

The abbé Mongez, and Mr. Lamanow, obſerved that ether evaporates with prodigious facility upon the peak of Teneriffe; and Mr. De Sauſſure has confirmed theſe experiments on the mountains of Switzerland.

A true diſtillation is carried on every where at the ſurface of our globe. The heat of the ſun raiſes water in the form of vapours; theſe remain a certain time in the atmoſphere, and afterwards fall in the form of dew, by ſimple refrigeration. This riſe and fall of humidity, which ſucceed each other, waſh and purge the atmoſphere of all thoſe particles, which by their corruption or development might render it infectious; and it is perhaps this combination of various miaſmata with water which renders the evening dew ſo unwholeſome.

It is to a ſimilar natural diſtillation that we ought to refer the alternate tranſition of water from the liquid ſtate to that of vapour, which forms clouds, and by this means conveys the water from the ſea to the ſummits of mountains, from which it is precipitated in torrents, to return again to the common receptacle.

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We find traces of the diſtillation of water in the moſt remote ages. The firſt navigators in the iſlands of the Archipelago filled their pots with ſalt-water, and received the vapour in ſponges placed over them. The proceſs of diſtilling the water of the ſea has been ſucceſſively brought to perfection; and Mr. Poiſſonnier has exhibited a very well conſtructed apparatus to procure freſh water at all times in abundance.

Pure water requires to be agitated, and combined with the air of the atmoſphere, to render it wholeſome. Hence, no doubt, it is, that water immediately produced by melting ſnow, is unfit to drink.

The characters of potable water are the following:

1. A lively, freſh, and agreeable taſte.

2. The property of boiling readily, and alſo that of boiling peaſe and other pulſe.

3. The virtue of diſſolving ſoap without curdling.

ARTICLE III.

Concerning Water in the State of Gas.

Many ſubſtances are naturally in the ſtate of an aëriform fluid, at the degree of the tempera-

ture

ture of our atmoſphere: ſuch, for example, are the carbonic acid; and the oxigenous, the hydrogenous, and the nitrigenous gaſes.

Other ſubſtances evaporate at a degree of heat very near that in which we live. Ether and alcohol are in this ſituation. The firſt of theſe liquors paſſes to the ſtate of gas at the temperature of 35 degrees; the ſecond, at that of 80 (of Reaumur).

Some fluids require a ſtronger heat for this purpoſe; ſuch as water, the ſulphuric and nitric acids, oil, &c.

To convert water into an aëriform fluid, Meſſrs. De la Place and Lavoiſier filled a glaſs veſſel with mercury, and reverſed it over a diſh filled with the ſame metal. Two ounces of water were transferred beneath this veſſel; and the mercury was heated to the temperature of between ninety-five and a hundred of Reaumur, by plunging it in a boiler filled with the mother water of nitre. The included water became rarefied, and occupied the whole capacity.

Water, by paſſing through earthen veſſels ignited in the fire, becomes converted into gas, according to Prieſtley and Kirwan. The æolipile, the ſteam-engine, the digeſter of Papin, and the proceſs of the glaſs-blowers, who blow large globes by injecting a mouthful of water through

through their iron tube, prove the converſion of water into gas.

It follows from theſe principles, that the volatilization of water being nothing more than a direct combination of caloric with this liquid, the portions of water which are the moſt immediately expoſed to heat, muſt be the firſt volatilized: and this is daily obſerved; for it is continually ſeen that ebullition begins at the part moſt heated. But when the heat is applied equally at all parts, the ebullition is general.

Several phenomena have led us to believe that water may be converted into air. The proceſs of the glaſs-blowers to blow large ſpheres; the hydraulic organ of father Kircher; the phenomena of the æolipile; the experiments of Meſſrs. Prieſtley and Kirwan; the manner of aſſiſting combuſtion, by ſprinkling a ſmall quantity of water upon the coals—all theſe circumſtances appeared to announce the converſion of water into air. But it was far from being ſuppoſed that moſt of theſe phenomena were produced by the decompoſition of this fluid; and the genius of Mr. Lavoiſier was neceſſary to carry this point of doctrine to the degree of certainty and preciſion, which in my opinion it now appears to poſſeſs.

Meſſrs. Macquer and De la Metherie had already

already obſerved, that the combuſtion of inflammable air produced much water. Mr. Cavendiſh confirmed theſe experiments in England, by the rapid combuſtion of inflammable air and vital air. But Meſſrs. Lavoiſier, De la Place, Monge, and Meuſnier, have proved that the whole maſs of the water might be converted into hydrogene and oxigene; and that the combuſtion of theſe two gaſes produced a volume of water proportioned to the weight of the two principles employed in this experiment.

1. If a ſmall glaſs veſſel be inverted over mercury, and a known quantity of diſtilled water and filings of iron be put into the upper part of this veſſel, inflammable air will be gradually diſengaged, the iron will ruſt, and the water which moiſtens it will diminiſh, and at length diſappear; the weight of the inflammable air which is produced, and the augmentation in weight of the iron, will be equivalent to the weight of the water made uſe of. It appears therefore to be proved, that the water is reduced into two principles, the one of which is inflammable air, and the other is the principle which has entered into combination with the metal. Now we know that the oxidation or calcination of metals is owing to vital air; and conſequently the two ſubſtances produced, namely

namely the vital air and inflammable air, ariſe from the decompoſition of water.

2. When water is converted into the ſtate of vapour, in its paſſage through an ignited iron tube, the iron becomes oxided, and hydrogene is obtained in the ſtate of gas. The augmentation of weight in the metal, and the weight of the hydrogene obtained, form preciſely a ſum equal to that of the water employed.

The experiment made at Paris, in the preſence of a numerous commiſſion of the Academy, appears to me to leave no further doubt concerning the decompoſition of water.

A gun-barrel was taken, into which a quantity of thick iron wire, flattened by hammering, was introduced. The iron and the gun-barrel were weighed: the gun-barrel was then covered with a lute proper to defend it from the contact of the air; it was afterwards placed in a furnace, and inclined in ſuch a manner as that water might run through it. At its moſt elevated extremity was fixed a funnel deſigned to contain water, and to let it paſs drop by drop by means of a cock: this funnel was cloſed, to avoid all evaporation of the water. At the other extremity of the gun-barrel was placed a tubulated receiver, intended to receive the water which might paſs without decompoſition;

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and to the tubulure of the receiver the pneumato-chemical apparatus was adapted. For greater precaution, a vacuum was made in the whole apparatus before the operation began. Laſtly, as ſoon as the gun-barrel was red-hot, the water was introduced drop by drop. Much hydrogenous gas was obtained: and at the end of the experiment the gun-barrel was found to have acquired weight; and the flat pieces of iron included within were converted into a ſtratum of black oxide of iron, or Ethiops martial, cryſtallized like the iron ore of the iſland of Elba. It was aſcertained that the iron was in the ſame ſtate as that which is burned in oxigenous gas; and the increaſed weight of the iron, added to that of the hydrogene, was accurately equal to that of the water employed.

The hydrogenous gas obtained was burned with a quantity of vital air equal to that which had been retained by the iron, and the ſix ounces of water were recompoſed.

3. Meſſrs. Lavoiſier and De la Place, by burning in a proper apparatus a mixture of fourteen parts of hydrogenous gas, and eighty-ſix of oxigene, obtained a proportionate quantity of water. Mr. Monge obtained the ſame reſult at Mezieres, at the ſame time.

The moſt concluſive and the moſt authentic

 experi-

experiment which was made upon the compoſition or ſyntheſis of water, is that which was begun on the 23d of May, and ended on the 7th of June, 1788, at the Royal College, by Mr. Lefevre de Gineau.

The volume of oxigenous gas conſumed, when reduced to the preſſure of twenty-eight inches of mercury, at the temperature of ten degrees of the thermometer of Reaumur, was 35085 (French) cubic inches, and its weight 250 gros 10,5 grains.

The volume of hydrogenous gas was 74967,4 cubic inches, and the weight 66 gros 4,3 grains.

The nitrogenous gas and the carbonic acid which were mixed with theſe gaſes, and which had been extracted out of the receiver at nine ſeveral times, weighed 39,23 grains.

The oxigenous gas contained $\frac{1}{38}$ of its weight of carbonic acid; ſo that the weight of the gaſes burned was 280 gros 63,8 grains, which makes 2 pounds 3 ounces 0 gros 63,8 grains.

The veſſels were opened in the preſence of the gentlemen of the Academy of Sciences, and ſeveral other learned men, and were found to contain 2 pounds 3 ounces 0 gros 33 grains of water: this weight anſwers to that of the gaſes made uſe of, wanting 31 grains; this deficiency

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may arise from the caloric which held the gases in solution being dissipated when they became fixed, which must necessarily have occasioned a loss.

The water was subacid to the taste, and afforded $27\frac{1}{2}$ grains of nitric acid, which acid is produced by the combination of the nitrogene and oxigene gases.

From the experiment of the decomposition of water, 100 parts of this fluid contained

Oxigene 84,2636 = $84\frac{1}{4}$.
Hydrogene 15,7364 = $15\frac{3}{4}$.

According to the experiment of its composition, 100 parts of water contained

Oxigene 84,8 = $84\frac{4}{5}$.
Hydrogene 15,2 = $15\frac{1}{5}$.

Independent of these experiments of analysis and synthesis, the phenomena exhibited by water, in its several states, confirm our ideas with regard to the constituent parts which we acknowledge it to possess. The oxidation of metals in the interior parts of the earth, at a distance from the atmospherical air, the efflorescence of pyrites, and the formation of ochres, are phenomena which cannot be explained without the assistance of this theory.

Water, being composed of two known principles, must act like all other compound bodies

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which we know; that is, according to the affinities of its conſtituent parts. It muſt therefore in ſome inſtances yield its hydrogene, and in others its oxigene.

If it be placed in contact with bodies which have the ſtrongeſt affinity with oxigene, ſuch as the metals, oils, charcoal, &c. the oxigenous principle will unite with theſe ſubſtances; and the hydrogene, being ſet at liberty, will be diſſipated. This happens when hydrogene gas is diſengaged, by cauſing the acids to act upon certain metals; or when red-hot iron is plunged in water, as Meſſrs. Haſſenfratz, Stoulſz, and D'Hellancourt have obſerved.

In vegetables, on the contrary, it ſeems that the hydrogene is the principle which fixes itſelf; while the oxigene is eaſily diſengaged, and makes its eſcape.

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SECTION VIII.

Concerning the Combinations of Nitrogene Gas, 1. With Hydrogene Gas. 2. With the Earthy Principles forming the Alkalis.

IT appears to be proved, that the combination of nitrogene gas with hydrogene forms one of the ſubſtances compriſed in the claſs of alkalis. It is very probable that the others are compoſed of this ſame gas and an earthy baſis. It is from theſe conſiderations that we have thought proper to place thoſe ſubſtances here: and we have adopted that deciſion with ſo much the more foundation, becauſe the knowledge of alkalis is indiſpenſably neceſſary to enable us to proceed with order in a courſe of chemiſtry; and becauſe theſe re-agents are moſt frequently employed, and their combinations and uſes preſent themſelves at every ſtep in the phenomena of nature and art.

It is an eſtabliſhed convention to call every ſubſtance an Alkali, which is characteriſed by the following properties:

A. An acrid, burning, urinous taſte.

B. The property of converting ſyrup of violets green; but not the tincture of turnſole, as certain authors announce.

C. The

C. The virtue of forming glafs, when fufed with quartzofe fubftances.

D. The faculty of rendering oils mifcible with water; of effervefcing with certain acids; and of forming neutral falts with all of them.

I muft obferve that none of thefe characters is rigorous and exclufive; and that confequently no one of them is fufficient to afford a certainty of the exiftence of an alkali: but the reunion of feveral forms, by their concurrence, a mafs of proofs or indications, which lead us to fufficient evidence.

The alkalis are divided into fixed alkalis and volatile alkalis. This diftinction is eftablifhed upon the fmell of thefe fubftances: the former are not volatilized, even in the focus of the burning mirror, and emit no characteriftic fmell; whereas the latter are eafily reduced into vapour, and emit a very penetrating odour.

CHAP. I.

Concerning Fixed Alkalis.

NO more than two kinds of fixed alkalis have hitherto been difcovered: the one which is called Vegetable Alkali, or Pot-Afh; the other Mineral Alkali, or Soda.

ARTI-

ARTICLE I.

Concerning the Vegetable Alkali, or Pot-Aſh.

This alkali may be extracted from various ſubſtances; and it is more or leſs pure, accordingly as it is afforded by one ſubſtance or another. Several varieties are made in commerce, to which different names have been affixed, and which are indiſpenſably neceſſary to be known. The chemiſt may indeed confound all theſe diſtinctions, in his writings, under one ſingle denomination: but the diſtinctions eſtabliſhed by the artiſts are founded upon a ſeries of experiments, which have proved that the virtues of theſe ſeveral alkalis are very different; and this conſtant variety in their effects appears to me to juſtify the various denominations aſſigned to them.

1. The alkali extracted from the lixivium of wood-aſhes, is known by the name of *Salin*. The *ſalin* calcined, and by this means diſengaged from all the blackening principles, forms pot-aſh.

The aſhes are more or leſs rich in alkali, according to the nature of the wood which affords them; in general, hard woods contain the moſt. The aſhes of beech afford from 11 to 13lb. per quintal,

quintal, according to the experiments which I have made in the large way, at St. Sauveur; thofe of box afforded from 12 to 14lb. The tables drawn up by the feveral adminiftrators of the gunpowder and faltpetre manufactories may be confulted, refpecting the quantity of alkali afforded by the combuftion of feveral plants: they ufed 4000lb. of each in their various experiments.

To extract this alkali, nothing more is neceffary than to wafh the afhes, and to concentrate the diffolution in boilers of caft iron. It is on account of the alkali that wood afhes are employed in the lixiviums ufed by laundreffes or bleachers. The ufe of alkali, in this cafe, is to combine with the fat fubftances, and to render them foluble in water.

Almoft all the pot-afh fold in commerce for the ufe of our glafs-houfes, our foap-makers, our bleaching-grounds, &c. is fabricated in the north, where the abundance of wood admits of its being applied to this fingle purpofe. We might eftablifh works of this kind to fufficient advantage in the forefts of our kingdom. But there is more to be done than is generally fuppofed, before the inhabitants of the mountains can be turned towards this fpecies of induftry. I have experienced this difficulty in the attempts

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and very confiderable facrifices which I have made to fecure this refource in the neighbourhood of Laigoual and Lefperou. The accurate calculations which I have made, have neverthelefs proved that the pot-afh would coft only from 15 to 17 livres the quintal, whereas we purchafe that from the north at 30 or 40 livres.

2. The lees of wine is almoft totally converted into alkali by combuftion. This alkali is called *Cendres Gravelées*: it has almoft always a greenifh colour. This alkali is confidered as very pure.

3. The combuftion of tartar of wine likewife affords an alkali of confiderable purity. It is ufually burned wrapped up in paper, in fmall packets, which are dipped in water, and afterwards expofed upon burning coals. In order to purify it, the refidue of the combuftion is diffolved in water, the folution concentrated by fire, the foreign falts feparated in proportion as they precipitate; and a very pure alkali is at laft obtained, which is known by the name of Salt of Tartar.

To procure falt of tartar more fpeedily, as well as more economically, I burn a mixture of equal parts of nitrate of pot-afh, or common nitre

nitre and tartar. The reſidue, after lixiviation, affords a beautiful ſalt of tartar.

Salt of tartar is the alkali moſt commonly employed in medical uſes; it is given in the doſe of ſeveral grains.

4. If ſaltpetre be fuſed upon charcoal, the acid is decompoſed and diſſipated, while the alkali remains alone and diſengaged: this is called Extemporaneous Alkali.

When the vegetable alkali has been brought to the greateſt ſtate of purity, it attracts the humidity of the air, and is reſolved into a liquor. In this ſtate it is known by the very improper name of Oil of Tartar per Deliquium.

ARTICLE II.

Concerning the Mineral Alkali, or Soda.

The Mineral Alkali has been ſo called, becauſe it forms the baſis of marine ſalt.

It is obtained from marine plants by combuſtion: for this purpoſe heaps of the ſaline plants are formed; and at the ſide of theſe heaps a round cavity is dug, which is enlarged towards the bottom, and is three or four feet in depth: this is the fire-place in which the vegetables are burned. The combuſtion is kept up without interrup-

interruption for ſeveral days; and when all the plants are conſumed, a maſs of alkaline ſalt is found remaining, which is cut into pieces, to facilitate its carriage and ſale. This is known by the name of Rock Soda, or Soda.

All marine plants do not afford ſoda of the ſame quality. The barilla of Spain affords the beautiful ſoda of Alicant. I am aſſured that we might cultivate it upon our coaſts in the Mediterranean, with the greateſt ſucceſs. This culture is highly intereſting to the arts and commerce; and government ought to encourage this new ſpecies of induſtry. But an individual, however inclined or devoted to the public good, might make vain efforts to appropriate this commerce to our advantage, if he were not powerfully aſſiſted by government; becauſe the Spaniſh miniſtry has prohibited the exportation of the ſeed of barilla, under the ſtrongeſt penalties. In Languedoc, and in Provence, we cultivate on the banks of our ponds a plant known by the name of Salicor, which affords ſoda of a good quality; but the plants which grow without cultivation produce an inferior ſort. I have made an accurate analyſis of each ſpecies, the reſults of which may be ſeen at the article *Verrerie* of the *Encyclopedie Methodique.*

The mineral alkali is cleared of all hetero-

geneous

geneous falts by diffolving it in water, and feparating the feveral falts in proportion as they fall down. The laft portion of the fluid being concentrated affords the foda, which cryftallizes in rhomboidal octahedrons.

The mineral alkali is fometimes found in a native ftate: in Egypt it is known by the name of Natron. The two lakes of Natron defcribed by Sicard and Mr. Volney, are fituated in the defert of Chaiat, or St. Macaire, to the weft of Delta. Their bed is a natural cavity of three or four leagues in length, and a quarter of a league in breadth; the bottom is folid and ftony. It is dry during nine months in the year; but in winter a water of a violet-red colour oozes out of the earth, which fills the lake to five or fix feet in depth: the return of the heat of fummer evaporates this, and leaves a bed of falt behind it of two feet in thicknefs, which is dug out with bars of iron. The quantity obtained annually amounts to 36,000 quintals.

Mr. Prouft found natron upon the fchifti which form the foundation of the town of Angers; the fame chemift likewife found it upon a ftone from the falpetriere of Paris.

The mineral alkali differs from the vegetable, becaufe—1. It is lefs cauftic. 2. It is fo far

far from attracting humidity, that it effloresces in the air. 3. It cryſtallizes in rhomboidal octahedrons. 4. It forms different products with the ſame baſes. 5. It is more proper for vitrification.

Do the alkalis exiſt ready formed in vegetables, or are they the product of the ſeveral operations made uſe of in extracting them?—This queſtion has divided the opinions of chemiſts. Du Hamel and Groſſe proved, in 1732, the exiſtence of alkali in cream of tartar, by treating it with the ſame nitric, ſulphuric, and other acids. Margraff has given additional proofs of this, in a Memoir which forms the twenty-fifth of his collection. Rouelle read a Memoir to the Academy on the 14th of June, 1769, upon the ſame ſubject: he even affirms that he was acquainted with this truth before the work of Margraff appeared.—See the Journal de Phyſique, vol. i.

Rouelle, and the marquis De Bullion, proved that tartar exiſts in muſt.

It muſt not be concluded from the exiſtence of an alkali in vegetables, that this ſalt is there found in a diſengaged ſtate. On the contrary, it is found combined with acids, oils, &c.

The alkalis, ſuch as we have deſcribed them, even after they have been diſengaged from every

every mixture, by ſolution, filtration, and evaporation, are not nevertheleſs in that ſtate of purity and diſengagement, which is neceſſary to be obtained in many caſes: they are nearly in the ſtate of neutral ſalts, by their combination with the carbonic acid. When it is required to diſengage this acid, the alkali muſt be diſſolved in water, and quick-lime then ſlaked in the ſolution. This ſubſtance ſeizes the carbonic acid of the alkali, and gives out its caloric in exchange. We ſhall ſpeak of the circumſtances of this operation when we ſhall have occaſion to treat of lime. The alkali being deprived of the carbonic acid, no longer effervefces with other acids; it is more cauſtic, and more violent in its action; unites more eaſily to oils; and is then called Cauſtic Alkali, Pure Pot-aſh, or Pure Soda.

When this alkali is evaporated, and brought into the dry form, it is known by the name of Lapis Cauſticus. The corroſive virtue of this ſubſtance depends principally upon the avidity with which it ſeizes humidity, and falls into deliquium.

The cauſtic alkali, as it is uſually prepared, always contains a ſmall quantity of carbonic acid, ſiliceous earth, iron, lime, &c. Mr. Berthollet has propoſed the following means of

purifying

purifying it:—He concentrates the cauſtic lixivium until it has acquired a ſlight degree of conſiſtence; at which period he mixes it with alcohol, and draws off a portion by diſtillation. As ſoon as the retort is become cold, he finds it to contain cryſtals, mixed with a blackiſh earth, in a ſmall quantity of liquor of a dark colour, which is ſeparated from the ſolution of alkali in the alcohol, which ſwims above like an oil. Theſe cryſtals conſiſt of the alkali ſaturated with the carbonic acid, and are inſoluble in ſpirit of wine; the depoſition conſiſts of ſiliceous earth, lime, iron, &c.

The cauſtic alkali in a ſtate of great purity, diſſolved in the alcohol, ſwims above the aqueous ſolution which contains the effervefcent alkali. If the ſpirituous ſolution of alkali be concentrated on the ſand-bath, tranſparent cryſtals are formed, which conſiſt of the pure alkali itſelf; theſe cryſtals appear to be formed by quadrangular pyramids inſerted one in another; they are very deliqueſcent, are ſoluble in water and in alcohol, and produce cold by their ſolution.—See the Journal de Phyſique, 1786, page 401.

The alkalis we have juſt ſpoken of, combine eaſily with ſulphur.

This combination may be effected—1. By the

fuſion

fuſion of equal parts of alkali and ſulphur. 2. By digeſting the pure and liquid alkali upon ſulphur.—In theſe caſes the alkali becomes of a reddiſh-yellow colour.

The ſolutions of ſulphur in alkali are known by the name of Livers of Sulphur, Sulphures of Alkali, &c. They emit an offenſive ſmell, reſembling that of rotten eggs. This is occaſioned by the eſcape of the ſtinking gas, called Hepatic Gas.

The ſulphur may be precipitated by acids; and the reſult of this precipitation is what the ancient chemiſts diſtinguiſhed by the name of Milk of Sulphur, and Magiſtery of Sulphur.

Theſe ſulphures or hepars diſſolve metals. Gold itſelf may be ſo divided by this means as to paſs through filters. Stahl has ſuppoſed that Moſes made uſe of this method to enable the Iſraelites to drink the golden calf.

Though the analyſis of the two alkalis has not been made with ſtrictneſs, ſeveral experiments lead us to believe that nitrogene is one of their principles. Mr. Thouvenel, having expoſed waſhed chalk to the exhalations of animal ſubſtances in putrefaction, obtained nitrate of pot-aſh, or common nitre. I have repeated this experiment in a cloſed chamber of ſix feet ſquare. Twenty-five pounds of chalk waſhed in warm water, and expoſed to the exhalation of bullock's bullock's blood in putrefaction during eleven months, afforded nine ounces of nitrate of lime, in a dried ſtate; and three ounces one gros of cryſtals of nitrate of pot-aſh, or common nitre.

The repeated diſtillation of ſoaps decompoſes them, and affords ammoniac. Now the analyſis of this laſt, by Mr. Berthollet, proves the exiſtence of nitrogenous gas as one of its conſtituent parts. There is therefore room to apprehend that nitrogene gas is one of the principles of alkalis.

The experiments of Mr. Thouvenel, as well as my own, lead me to believe that this gas, when combined with lime, forms pot-aſh, or the vegetable alkali; while its union with magneſia forms ſoda. This laſt opinion is ſupported by the experiments—1. Of Dehne, who obtained magneſia from ſoda (ſee Crell's Chemical Annals, 1781, page 53). 2. Of Mr. Deyeux, who obtained ſimilar reſults even before Mr. Dehne. 3. Of Mr. Lorgna, who obtained much magneſia by diſſolving, evaporating, and calcining ſoda repeatedly (Journal de Phyſique, 1787). Mr. Oſburg confirmed theſe various experiments in 1785.

CHAP. II.

Concerning Ammoniac, or the Volatile Alkali.

OUR refearches have not hitherto exhibited more than one fpecies of volatile alkali. Its formation appears to be owing to putrefaction; and though the diftillation of fome fchifti affords it, yet this circumftance may be attributed to their origin, which is pretty generally afcribed to vegetable and animal decompofition. We find frequently enough, in thefe fubftances, the print of fifhes, which is in favour of this opinion. Some plants likewife afford volatile alkali; for which reafon they have been called Animal Plants. But the volatile alkali is more efpecially afforded by animal fubftances: the diftillation of all their parts affords it in confiderable abundance. Horns are employed in preference, becaufe they are refolved almoft entirely into oil and volatile alkali. The putrefaction of all animal fubftances produces volatile alkali; and in this cafe, as well as in diftillation, it is formed by the combination of its two conftituent parts: for the analyfis very often fails in exhibiting any alkali

ready

ready formed, in ſuch parts as diſtillation or putrefaction would abundantly afford it from.

Almoſt all the volatile alkali made uſe of in commerce or medicine, is afforded by the decompoſition of ſal ammoniac. It is even on account of this circumſtance that the chemiſts who have drawn up the New Nomenclature have diſtinguiſhed the volatile alkali by the name of Ammoniac.

To obtain ammoniac in a ſtate of conſiderable purity, equal parts of ſifted quick-lime and muriate of ammoniac, or common ſal ammoniac in powder, are mixed. This mixture is then introduced into a retort, to which a receiver and the apparatus of Woulfe have been adapted. A quantity of pure water is to be put into the bottles, correſpondent to the weight of the ſalt employed; and the junctures of the veſſels are made good with the uſual lutes. The ammoniac is diſengaged in the ſtate of gas, at the firſt impreſſion of the fire. It combines with the water with heat; and when the water of the firſt bottle is ſaturated, the gas paſſes to that of the ſecond, and ſaturates it in its turn.

Volatile alkali is known by its very ſtrong but not diſagreeable ſmell. It is eaſily reducible into the ſtate of gas, and preſerves this form at the temperature of the atmoſphere. This gas may be obtained by decompoſing the muriate of ammoniac by quick-lime, and receiving the product over mercury.

Alkaline gas kills animals, and corrodes the ſkin. The irritation is ſuch, that I have ſeen pimples ariſe all over the bodies of ſome birds expoſed to its atmoſphere.

This gas is improper for combuſtion; but if a taper be gently immerſed in it, the flame is enlarged before it goes out, and the gas ſuffers a decompoſition. Alkaline gas is lighter than atmoſpheric air; and has even been mentioned, on account of its lightneſs, as a proper ſubſtance to fill balloons. The count De Milly propoſed to place a brazier, or veſſel containing fire, under the balloon, to keep the gas in its greateſt ſtate of expanſibility.

The experiments of Dr. Prieſtley, who changed alkaline gas into hydrogene gas by means of the electric ſpark; thoſe of the chevalier Laudriani, who, by paſſing the ſame gas through ignited glaſs tubes, obtained a large quantity of hydrogenous gas—occaſioned a ſuſpicion of the exiſtence of hydrogene among the principles of alkaline gas. But the experiments of Mr. Berthollet have removed all doubts on this ſubject; and all obſervations appear to unite in authoriſing us to conſider this alkali as a compound of the nitrogenous and hydrogenous gafes.

1. If the oxigenated muriatic acid be mixed with very pure ammoniac, an effervefcence takes place, with a difengagement of nitrogenous gas, a production of water, and a converfion of the oxigenated acid into the ordinary muriatic acid. In this beautiful experiment, the water which is produced is formed by the combination of the hydrogene of the alkali and the oxigene of the acid; and the nitrogene gas being fet at liberty, is diffipated.

2. When the nitrate of ammoniac is expofed to diftillation, nitrogene gas is obtained, and a greater quantity of water is found in the receiver than the falt itfelf contained. After the operation, the ammoniac is found no longer to exift. The water of the receiver is flightly charged with a fmall quantity of nitric acid, which had paffed over. In this cafe, the hydrogene of the alkali, and the oxigene of the acid, form the water in the receiver, while the nitrogenous gas efcapes.

If the oxides of copper or gold be heated with ammoniacal gas, the product is water and nitrogenous gas, and the metals are reduced.

I have obferved that the oxides of arfenic, being digefted with ammoniac, are reduced,

and

and often form octahedral cryſtals of arſenic. In this caſe there is a diſengagement of nitrogene gas, and a formation of water.

It very often happens when metals, ſuch as copper or tin, are diſſolved by means of the nitric acid, that an abſorption of air takes place, inſtead of a diſengagement of nitrous gas, as might be expected: I have ſeen ſeveral perſons very much embarraſſed in ſuch caſes, and I have often been ſo myſelf. This phenomenon takes place more eſpecially when a very concentrated acid is made uſe of, and the copper is in fine filings: in this caſe ammoniac is produced. I have ſhewn this fact to my auditors long before I was acquainted with the theory of its formation. That which led me to ſuſpect its exiſtence, was the blue colour which the ſolution takes in this caſe. This ammoniac is produced by the combination of the hydrogene of the water with the nitrogene gas of the nitric acid; while the oxigene of the ſame acid, and that of the water, oxided the metal, and prepared it for ſolution. It is to a ſimilar cauſe that we muſt refer the experiment of Mr. John Michael Hauſſman of Colmar, who by paſſing nitrous gas through a certain quantity of precipitate of iron, in the mercurial apparatus, obſerved that this gas was ſpeedily abſorbed, and the

the colour of the iron changed; at the ſame time that vapour of ammoniac was found in the veſſels. It is by a ſimilar theory we may account for the formation of alkaline gas, by the mixture of hepatic gas and nitrous gas over mercury, as Mr. Kirwan obſerves.

Mr. Auſtin formed ammoniac; but he obſerved that the combination of nitrogenous gas with the baſe of hydrogene does not take place, unleſs this laſt is in a ſtate of great condenſation.

The formation of ammoniac by diſtillation and putrefaction, appears to me likewiſe to indicate its conſtituent parts. In fact, there is in both theſe operations a diſengagement of hydrogene and nitrogene gas, and their combination produces ammoniac.

Mr. Berthollet has proved, by the way of decompoſition, that one thouſand parts of ammoniac, by weight, are compoſed of about eight hundred and ſeven of nitrogene gas, and one hundred and ninety-three of hydrogene gas. —See the collection of the Royal Academy, 1784, page 316.

According to Dr. Auſtin, the nitrogene gas is in proportion to the hydrogene, as one hundred and twenty-one to thirty-two.

SECTION IX.

Concerning the Combination of Oxigene with certain Baſes forming Acids.

IT appears to be out of doubt, that the bodies which we are agreed to call Acids, are combinations of vital air with a certain elementary ſubſtance. The analyſis of almoſt all the acids, whoſe component parts are known, eſtabliſhes this truth in a poſitive manner; and it is on account of this property that the denomination of Oxigenous Gas has been given to vital air.

Every ſubſtance which poſſeſſes the following properties is called an Acid:

A. The word *ſour*, which is uſually employed to denote the impreſſion or lively and ſharp ſenſation produced on the tongue by certain bodies, may be regarded as ſynonymous to the word *acid*. The only difference which may be eſtabliſhed between them is, that the one denotes a weak ſenſation, whereas the other comprehends all the degrees of force from the leaſt perceptible taſte to the greateſt degree of cauſticity. We ſay that verjuice, gooſeberries, or lemons, are *ſour*; but we uſe the word *acid* to expreſs the impreſſion which the nitric, ſulphuric, or muriatic acids make upon the tongue.

The

The causticity of acids appears to arise from their strong tendency to combination; and it is from this property that the immortal Newton has defined them to be bodies which attract and are attracted.

It is also from this property that certain chemists have supposed acids to be pointed bodies.

On account of this decided tendency to combination which acids possess, it seldom happens that we find them in a disengaged state.

B. A second property of acids is that of changing certain blue vegetable colours into red, such as the colour of turnsole, syrup of violets, &c. These two re-agents are commonly used to ascertain the presence of acids.

The tincture of turnsole is prepared by lightly infusing in water that substance which is known in common under the name of Turnsole or Litmus. If the water be too lightly charged with the colouring matter, the infusion has a violet tinge, and must in that case be diluted with water until it becomes blue. The tincture of turnsole, when exposed to the sun, becomes red, even in closed vessels; and some time afterwards the colouring part is disengaged, and falls down in the form of a mucilaginous discoloured substance. Alcohol may be used instead of water in the preparation of this tincture.

It

It is generally ſuppoſed that the turnſole fabricated in Holland is nothing more than the colouring matter extracted from the rags or cloths of turnſole of Grand-Galargues, and precipitated upon a marly earth. Theſe rags are prepared by impregnating them with the juice of nightſhade (morelle), and expoſing them to the vapour of urine, which develops their blue colour. The rags are ſent into Holland, which has given riſe to the opinion that they are uſed in the fabrication of turnſole; but ſubſequent enquiries have taught me that theſe cloths are ſent to the dealers in cheeſe, who extract a colour by infuſion, and waſh their cheeſes with it, to give them a red colour. I am convinced by the analyſis of turnſole, that the colouring matter is of the ſame nature as that of archil (orſeille); and that this principle is fixed on a calcareous earth, and a ſmall quantity of pot-aſh. In conſequence of this analyſis, I have endeavoured to cauſe the liken parellus of Auvergne to ferment with urine, lime, and alkali; and I obtained a paſte ſimilar to that of turnſole. The addition of alkali appears to me to be neceſſary to prevent the development of the red colour, which, when combined with the blue, forms the violet of the archil.

When any concentrated acid is to be tried with

with ſyrup of violets, there are two particulars to be attended to. 1. The ſyrup of violets is often green, becauſe the petal of the violet contains a yellow part at its baſe, which, when combined with the blue, forms this green colour: it is therefore eſſential to employ only the blue of the petal in order to have a beautiful blue infuſion. 2. Care muſt be taken to dilute the ſyrup with a certain quantity of water; becauſe otherwiſe concentrated acids, ſuch as the ſulphuric, would burn it, and form a coal.

The ſimple infuſion of violets may be uſed inſtead of the ſyrup.

The colouring matter of indigo is not ſenſible to the impreſſion of acids. The ſulphuric acid diſſolves it without altering the colour.

C. A third character of acids is, they effervеſce with alkalis; but this property is not general. 1. Becauſe the carbonic acid, and almoſt all weak acids, cannot be diſtinguiſhed by this property. 2. Becauſe the pureſt alkalis combine with acids, without motion or effervеſcence.

Is there not one ſingle acid in nature, of which the others may be only modifications?

Paracelſus admitted an univerſal principle of acidity, which communicated taſte and ſolubility to all its compounds.

Becher believed that this principle was compoſed

poſed of water and vitrifiable earth. Stahl endeavoured to prove that the ſulphuric acid was the univerſal acid; and his opinion was adopted by moſt chemiſts for a long time.

Long after the time of Stahl, Meyer maintained that the acid element was contained in fire. This ſyſtem, which is founded on certain known facts, has had its ſupporters.

The chevalier Landriani imagined he had ſucceeded in reducing all the acids to the carbonic acid; becauſe, by treating them all with different ſubſtances, he obtained this laſt as the conſtant reſult of his analyſis. He was led into an error, for want of having ſufficiently attended to the decompoſition of the acids he made uſe of, and the combination of their oxigene with the carbone of the bodies which entered into his experiments, and produced the carbonic acid.

Laſtly, the ſtrict analyſis and ſyntheſis of moſt of the known acids, have proved to Mr. Lavoiſier that oxigene is the baſe of all of them; and that their differences and varieties ariſe only from the ſubſtance with which this common principle is combined.

Oxigene united with metals forms oxides; and among theſe laſt there are ſome which poſſeſs acid characters, and are claſſed amongſt acid ſubſtances.

Oxigene

Oxigene combined with inflammable ſubſtances, ſuch as ſulphur, carbone, and oils, forms other acids.

The action of acids upon bodies in general cannot be underſtood but by founding our explanations upon the data which we have eſtabliſhed reſpecting the nature of their conſtituent parts.

The adheſion of oxigene to the baſe is more or leſs ſtrong in the ſeveral acids, and conſequently their decompoſition is more or leſs eaſy; as, for example, in metallic ſolutions, which do not take place excepting when the metal is in the ſtate of an oxide. The acid which will yield its oxigene with the greateſt facility to oxide the metal, will have the moſt powerful action upon it. Hence it happens, that the nitre and the nitro-muriatic acids are thoſe which diſſolve metals the moſt readily; and hence likewiſe it happens that the muriatic acid diſſolves the oxides more eaſily than the metals, while the nitric acid acts contrariwiſe: hence alſo it ariſes that this laſt acts ſo powerfully upon oils, &c.

It is impoſſible to conceive and explain the various phenomena preſented to us by acids in their operations, if we have no idea of their conſtituent principles. Stahl would not have believed in the formation of ſulphur, if he had under-

understood the decomposition of the sulphuric acid upon charcoal; and if we except the combinations of acids with alkalis, and with certain earths, these substances are either totally or partially decomposed in all the operations made with them upon metals, vegetables, and animals, as we shall find by observing the phenomena exhibited in these cases respectively.

We shall at present treat only of some of the acids, and shall direct our attention to the others in proportion as we shall have occasion to treat of the various substances which afford them: we shall attend in preference to those which are the best known, and which have the greatest influence in the operations of nature, as well as in those of our laboratories.

CHAP. I.

Concerning the Carbonic Acid.

THIS acid is almost always observed in the state of gas. We find that the ancients were in some measure acquainted with it. Van Helmont called it Gas Silvestre, the gas of must, or of the vintage. Becher himself had a considerably accurate notion of it, as appears by the fol-

following paſſage: “ Diſtinguitur autem inter “ fermentationem apertam et clauſam; in apertâ “ potus fermentatus ſanior eſt, ſed fortior in “ clauſâ: cauſa eſt, quod evaporantia rarefacta “ corpuſcula, imprimis magna adhuc ſilveſtri- “ um ſpirituum copia, de quibus antea egimus, “ retineatur, et in ipſum potum ſe precipitet, “ unde valde eum fortem reddit.”

Hoffmann attributed the virtue of moſt mineral waters to an elaſtic ſpirit contained in them.

Mr. Venel, a celebrated profeſſor in the ſchools at Montpellier, proved in 1750 that the waters of Seltzer owed their virtue to a ſuperabundant portion of air.

In 1755, Dr. Black of Edinburgh advanced that lime-ſtone contains much air of a different nature from common air. He affirmed that the diſengagement of this air converted it into lime, and that by the reſtoration of this air calcareous ſtone was regenerated. In the year 1746, Dr. M‘Bride ſupported this doctrine with new facts. Mr. Jacquin, profeſſor of Vienna, reſumed the ſame purſuit, multiplied experiments on the manner of extracting this air, and added other proofs in confirmation that the abſence of the air rendered alkalis cauſtic, and formed lime. Dr. Prieſtley exhibited all the perſpicuity and pre-

precision on this subject which might be expected from his abilities, and his skill in making experiments of this kind. This substance was then known by the name of Fixed Air. In 1772, Bergmann proved that it is an acid, which he called by the name of Aerial Acid. Since the time of this celebrated chemist, it has been distinguished by the names of Mephitic acid, Cretaceous acid, &c.: and as soon as it was proved to consist of a combination of oxigene and carbone, or pure charcoal, the name of Carbonic acid was appropriated to it.

The carbonic acid is found in three different states. 1. In that of gas. 2. In a state of mixture. 3. In a state of combination.

It is found in the state of gas at the Grotto del Cano, near Naples; at the well of Perols, near Montpellier; in that of Negrae in Vivarais; upon the surface of the Lake Averno in Italy, and on those of several springs; in various subterraneous places, such as tombs, cellars, necessaries, &c. It is disengaged in this form by the decomposition of vegetables heaped together, by the fermentation of wine or beer, by the putrefaction of animal matters, &c.

It exists in the state of simple mixture in mineral waters, since in these it possesses all its acid properties.

It exiſts in a ſtate of combination in lime-ſtone, common magneſia, alkalis, &c.

Various proceſſes are employed to collect it, according to the ſtate in which it is found.

I. When the carbonic acid exiſts in the ſtate of gas, it may be collected—1. By filling a bottle with water, and emptying it into the atmoſphere of this gas; the acid takes the place of the water, and the bottle is afterwards corked to retain it. 2. By expoſing lime-water, cauſtic alkalis, or even pure water, in its atmoſphere: the gaſeous acid mixes or combines with theſe ſubſtances; and may be afterwards extracted by re-agents, which we ſhall proceed to deſcribe.

II. When the carbonic acid exiſts in a ſtate of combination, it may be extracted—1. By diſtillation with a ſtrong heat. 2. By the reaction of other acids, ſuch as the ſulphuric acid, which has the advantage of not being volatile, and conſequently is not altered by its mixture with the carbonic acid which is diſengaged.

III. When the carbonic acid exiſts in the ſtate of ſimple mixture, as in water, briſk wines, &c. it may be obtained—1. By agitation of the liquid which contains it; as Mr. Venel practiſed, by making uſe of a bottle to which he adapted a moiſtened bladder.

2. By diſtillation of the ſame fluid.—Theſe two firſt methods are not accurate.

3. The procefs indicated by Mr. Gioanetti, confifts in precipitating the carbonic acid by means of lime-water, weighing the precipitate, and deducting thirteen thirty-fecond parts for the proportion of carbonic acid; it having been deduced from analyfis, by this celebrated phyfician, that thirty-two parts of carbonate of lime contain feventeen lime, two water, and thirteen acid.

This fubftance is an acid, as is proved—1. Becaufe tincture of turnfole, agitated in a bottle filled with this gas, becomes red. 2. Ammoniac, or volatile alkali, poured into a veffel filled with the gas, is neutralized. 3. Water impregnated with this gas is ftrongly fub-acid. 4. It neutralizes alkalis, and caufes them to cryftallize.

It remains at prefent to examine the properties of this acid gas.

A. It is unfit for refpiration. Hiftory informs us that two flaves whom Tiberius caufed to defcend into the Grotto del Cano, were immediately ftifled; and two criminals that Peter de Toledo caufed to be fhut in there, fuffered the fame fate. The abbé Nollet, who had the courage to refpire the vapour, perceived a fuffocating fenfation, and a flight degree of acidity, which produced coughing and fneezing. Pilatre

tre de Rosier, who presents himself to our notice on all occasions wherein danger was to be faced, caused himself to be fastened by cords fixed under his arms, and descended into the gaseous atmosphere of a back of beer in fermentation. He had scarcely entered into the mephitis before slight prickings obliged him to shut his eyes; a violent suffocation prevented him from respiring; he felt a giddiness, accompanied with those noises which characterize the apoplexy: and when he was drawn up, his sight remained dim for several minutes; the blood had filled the jugulars; his countenance had become purple; and he neither heard nor spoke but with great difficulty: all these symptoms however disappeared by degrees.

It is this gas which produces the many unhappy accidents at the opening of cellars, in places where wine, cyder, or beer are suffered to ferment. Birds plunged in the carbonic acid gas, suddenly perish. The famous Lake of Averno, where Virgil placed the entrance of hell, exhales so large a quantity of carbonic acid, that birds cannot fly over it with impunity. When the waters of Boulidou of Perols are dry, such birds as attempt to quench their thirst in the clefts, are enveloped in the mephitic vapour, and die.

O 2 Frogs,

Frogs, plunged in an atmofphere of carbonic acid, live from forty to fixty minutes, by fufpending their refpiration.

Infects are rendered torpid after a certain time of remaining in this air; but they refume their livelinefs the moment they are expofed to the free air.

Bergmann pretended that this acid fuffocates by extinguifhing irritability: he founds his opinion upon the circumftance of his having taken out the heart of an animal which had died in the carbonic acid, before it was cold, and it exhibited no fign of irritability. The chevalier Landriani has proceeded ftill further; for he affirms that this gas extinguifhes irritability, even when applied to the fkin; and has afferted that, by tying a bladder full of this gas to the neck of a fowl, in fuch a manner that the head only of the animal was in the open air, and the whole body enveloped in the bladder, the fowl immediately perifhed. The abbé Fontana has repeated and varied this experiment on feveral animals, none of which died.

The count Morrozzo publifhed experiments made in the prefence of Dr. Cigna; the refults of which appear to invalidate the confequences of the celebrated Bergmann: but it is to be obferved, that the chemift of Turin

Turin caused his animals to die only in air vitiated by the death of another animal; and that in this circumftance the nitrogene gas predominates.—See the Journal de Phyfique, tom. xxv. p. 112.

B. The carbonic acid is improper for vegetation. Dr. Prieftley having kept the roots of feveral plants in water impregnated with the carbonic acid, obferved that they all perifhed; and in thofe inftances where plants are obferved to vegetate in water or in air which contains this gas, the quantity of gas is very fmall.

Mr. Senebier has even obferved, that plants which are fuffered to grow in water flightly acidulated with this gas, emit a much larger quantity of oxigenous gas; becaufe, in this cafe, the acid is decompofed, the carbonaceous principle combines and is fixed in the vegetable, while the oxigene is thrown off.

I have obferved that thofe fungi which are formed in fubterraneous places, are almoft totally refolved into carbonic acid; but if thefe vegetables be gradually expofed to the action of light, the proportion of acid diminifhes; while that of the coaly principle augments, and the vegetable becomes coloured. I have purfued thefe experiments with the greateft care in a coal mine.

C. The carbonic acid is eafily diffolved in water. Water impregnated with this acid poffeffes very valuable medicinal qualities; and feveral apparatus have been fucceffively invented to facilitate this mixture. The apparatus of Nooth, improved by Parker and Magellan, is one of the moft ingenious. On this fubject the Encyclopédie Méthodique may be confulted, article Acide Mephitique.

The natural acidulous mineral waters do not differ from thefe, excepting in confequence of their holding other principles in folution; and they may be perfectly imitated when their analyfis is well known. It is abfurd to think that art is incapable of imitating nature in the compofition of mineral waters. It muft be admitted that the proceffes of nature are abfolutely unknown to us, in all the operations which relate to life; and we cannot flatter ourfelves with the hope of imitating her in thefe circumftances. But when the queftion relates to an operation purely mechanical, or confifting of the folution of certain known principles in water, we can and ought to perform it even ftill better, as we have the power of varying the dofes; and proportioning the efficacy of any artificial mineral water to the purpofes to which it is intended to be applied.

D. The

D. The carbonic acid gas is heavier than common air. The proportion between theſe two airs in weight, according to Mr. Kirwan, is 45,69 to 68,74. The proportion, according to the experiments of Mr. Lavoiſier, is 48,81 to 69,50.

This conſiderable weight cauſes it to occupy the loweſt ſituations; and even gives it the property of being poured out from one veſſel to another, ſo as to diſplace the atmoſpheric air. This truly curious phenomenon was obſerved by Mr. De Sauvages, as may be ſeen in his Diſſertation upon Air, which was crowned in Marſeilles in 1750.

It appears to be proved, by ſufficient experiments, that the carbonic acid is a combination of carbone, or pure charcoal, and oxigene. 1. The oxides of mercury, when diſtilled, are reducible without addition, and afford only oxigenous gas; but if a ſmall quantity of charcoal be mixed with the oxide, the product which comes over conſiſts of carbonic gas only, and the weight of the charcoal is diminiſhed.

2. If well-made charcoal be ignited, and plunged into a veſſel filled with oxigenous gas, and the veſſel be inſtantly cloſed, the charcoal burns rapidly, and at laſt goes out: the product in this experiment is carbonic acid, which

which may be ſeparated by the known proceſſes; the remainder is a ſmall quantity of oxigenous gas, which may be converted into carbonic acid by the ſame treatment.

In theſe experiments I ſee nothing but charcoal and oxigenous gas: and the conſequence deduced is ſimple and natural.

The proportion of charcoal is to that of oxigene as 12,0288 to 56,687.

When the carbonic acid, in ſome caſes, is obtained by burning hydrogenous gas, it ariſes from carbone held in ſolution in this gas. The carbone may even be diſſolved in hydrogenous gas, by expoſing it to the focus of the burning mirror in the mercurial apparatus, under a glaſs veſſel filled with this gas.

The hydrogenous gas which is extracted from a mixture of ſulphuric acid and iron, holds more or leſs of charcoal in ſolution; becauſe iron itſelf contains this ſubſtance in a greater or leſs quantity, as is aſcertained by the fine experiments of Meſſrs. Berthollet, Monge, and Vander Monde.

The alkalis, ſuch as we uſually meet with them, contain carbonic acid; and it is this acid which modifies them, and diminiſhes their energy, at the ſame time that it communicates to them the property of effervefcing. We may therefore

therefore conſider alkalis as carbonates with exceſs of alkali; and it is eaſy to ſaturate this ſuperabundant alkali, and to form true cryſtallizable neutral ſalts.

ARTICLE I.

Carbonate of Pot-aſh.

The carbonate of pot-aſh was formerly diſtinguiſhed by the name of Cretaceous Tartar. The method of cauſing oil of tartar to cryſtallize, has long been known. Bonhius and Montet have ſucceſſively ſhewn theſe proceſſes: but the ſimpleſt conſiſts in expoſing an alkaline ſolution in an atmoſphere of the acid gas which is diſengaged in the vinous fermentation; the alkali becomes ſaturated, and forms tetrahedral priſmatic cryſtals terminated by very ſhort four-ſided pyramids.

I have ſeveral times obtained thoſe cryſtals in the form of quadrangular priſms, with their extremities cut off ſlantwiſe.

This neutral ſalt no longer poſſeſſes the urinous taſte of the alkali, but exhibits the penetrating taſte of neutral ſalts, and may be employed in medicine with the greateſt ſucceſs. I have been a witneſs to its being taken in the doſe of one dram (gros) without the leaſt inconvenience.

This

This ſalt poſſeſſes an advantage beyond the ſalt of tartar, in being leſs cauſtic, and always of the ſame virtue.

It contains, according to the analyſis of Bergmann, twenty parts acid, forty-eight alkali, and thirty-two water, in the quintal.

It does not attract the humidity of the air. I have preſerved ſome of it for ſeveral years in a capſule, without any appearance of alteration.

The carbonate of pot-aſh is decompoſed by ſilex in a ſufficient heat, which occaſions a conſiderable boiling or ebullition. The reſidue is glaſs, in which the alkali is in the cauſtic ſtate. Lime decompoſes the carbonate, by uniting to the acid; and acids produce the ſame effect, by combining with the alkaline baſes.

ARTICLE II.

Carbonate of Soda.

The denominations of Aërated Mineral alkali, Cretaceous Soda, &c. have been ſucceſſively given to this kind of carbonate.

The mineral alkali, in its natural ſtate, contains a greater quantity of carbonic acid than the vegetable; and nothing more is neceſſary than to diſſolve it, and duly evaporate the water, in order to obtain it in cryſtals.

Theſe

Theſe cryſtals are uſually rhomboidal octahedrons; and ſometimes have the form of rhomboidal laminæ, applied obliquely one upon the other, ſo that they reſemble tiles.

This carbonate effloreſces in the air.

One hundred parts contain ſixteen parts acid, twenty alkali, and ſixty-four water.

The affinity of its baſis with ſilex is ſtronger than that of the carbonate of pot-aſh; in conſequence of which, the vitrification it produces is more quick and eaſy.

Lime and the acids decompoſe it, with the ſame phenomena which we have obſerved at the article Carbonate of Pot-aſh.

ARTICLE III.

Carbonate of Ammoniac.

This ſalt has been generally known by the name of Concrete Volatile Alkali. It has likewiſe been diſtinguiſhed by that of Cretaceous Volatile Alkali, &c.

It may be obtained by diſtillation from many animal ſubſtances. Tobacco affords, likewiſe, a large proportion; but almoſt the whole of that which is employed in the arts, and in medicine, is formed by the direct combination of the carbonic acid and ammoniac, or volatile alkali.

kali. This combination may be effected—1. By paſſing the carbonic acid through ammoniac, or the pure volatile alkali in ſolution. 2. By expoſing ammoniac in an atmoſphere of carbonic acid gas. 3. By decompoſing the muriate of ammoniac by the neutral ſalts which contain this acid, ſuch as the carbonate of lime or common chalk. For this purpoſe, white chalk is taken, and very accurately dried; and then mixed with equal parts of muriate of ammoniac, or common ſal ammoniac in fine powder. This mixture is put into a retort, and diſtilled; the ammoniac and the carbonic acid being diſengaged from their baſes, and reduced into vapours, combine together, and are depoſited on the ſides of the receiver, where they form a ſtratum more or leſs thick.

The cryſtallization of this carbonate appeared to me to be that of a four-ſided priſm, terminated by a dihedral ſummit.

The carbonate has leſs ſmell than the ammoniac; it is very ſoluble in water. Cold water diſſolves its own weight of this ſalt, at the temperature of ſixty degrees of Fahrenheit.

One hundred grains of this ſalt contain forty-five parts acid, forty-three alkali, and twelve water, according to Bergmann.

Moſt acids decompoſe it, and diſplace the carbonic acid.

CHAP.

CHAP. II.

Concerning the Sulphuric Acid.

SULPHUR, like every other combuftible fubftance, cannot be burnt but by virtue of the oxigenous gas which combines with it.

The moft ufual phenomena which accompany this combuftion, are, a blue flame, a whitifh and fuffocating vapour, and a ftrong, penetrating, and difagreeable fmell.

The refults of this combination vary according to the proportion in which thefe two principles enter into this fame combination.

The fulphureous or the fulphuric acid may be at pleafure obtained from fublimed fulphur, or from crude fulphur, accordingly as a greater or lefs quantity of oxigene is combined with the fulphur, by means of combuftion.

When the current of air which maintains the combuftion is rapid, the fulphur is carried, and depofited without any apparent alteration, into the internal part of the leaden chambers in which the oil of vitriol is made. If the current of air be rendered more moderate, the combination is fomewhat more accurate; the fulphur is is partly changed, and is depofited in a pellicle upon the furface of the water. This pellicle is flexible like a fkin, and may be handled and turned over in the fame manner. If the current be ftill lefs rapid, and the air be fuffered to have a fufficient time to form an accurate combination with the fulphur, the refult is fulphureous acid; which acid preferves its gafeous form at the temperature of the atmofphere, and may become liquid like water by the application of cold, according to the fine experiments of Mr. Monge. If the combuftion be ftill flower, and the air be fuffered to digeft upon the fulphur a longer time, and with greater accuracy, the refult is fulphuric acid: this laft combination may be facilitated by the mixture of faltpetre, becaufe this fubftance furnifhes oxigene very abundantly.

Numerous experiments which I have made in my manufactory, to economize the faltpetre employed in the fabrication of oil of vitriol, have feveral times exhibited the refults here mentioned.

All the proceffes which are capable of being adapted for extracting the fulphuric acid, are reducible to—1. The extraction of it from fubftances which contain it. 2. Its direct formation by combination of fulphur and oxigene.

In

In the firſt caſe, the ſulphures, or vitriolic ſalts of iron, copper, or zinc, and even thoſe whoſe baſes are clay and lime, according to Neumann and Margraff, may be expoſed to diſtillation. But theſe expenſive proceſſes are not very eaſy to be carried into execution; and accordingly they have been abandoned, to make room for others of greater ſimplicity.

In the ſecond caſe, the oxigene may be preſented to the ſulphur in two forms: either in the ſtate of gas, or in the concrete ſtate.

1. The combuſtion of ſulphur by oxigenous gas, is performed in large chambers lined with lead. The combuſtion is facilitated by mixing about one-eighth of a nitrate of pot-aſh with the ſulphur. The acid vapours which fill the chamber are precipitated againſt its ſides, and the condenſation is facilitated by a ſtratum of water diſpoſed on the bottom of the chamber. In ſome manufactories in Holland, this combuſtion is performed in large glaſs balloons with large mouths, and the vapours are precipitated upon water placed at the bottom.

In both caſes, when the water is ſufficiently impregnated with acid, it is concentrated in leaden boilers, and rectified in glaſs retorts, to render it white, and to concentrate it ſufficiently for the purpoſes of trade. The acid, when of a due

due ſtrength, indicates ſixty-ſix degrees, according to the acrometer of Mr. Baumé; and when it has not been carried to this degree, it is unfit for moſt of the uſes for which it is intended. It cannot, for example, be employed in diſſolving indigo; for the ſmall quantity of nitric acid which it contains, unites with the blue of the indigo, and forms a green colour. I have aſcertained this phenomenon by very accurate experiments; and I have been a witneſs to the failing of colours, and the loſs of ſtuffs, in conſequence of the imperfection of the acid.

2. When the oxigene in the concrete ſtate is preſented to the ſulphur, it is then in combination with other bodies, which it abandons to unite with this laſt. This happens when the nitric acid is diſtilled from ſulphur. Forty-eight ounces of this acid, at thirty-ſix degrees, diſtilled from two ounces of ſulphur, afforded near four ounces of good ſulphuric acid. This fact was known to Matte Lafaveur: but I pointed out all the phenomena and circumſtances of the operation in 1781.

Sulphur may likewiſe be converted into ſulphuric acid by means of the oxigenated muriatic acid.—Encyclopédie Méthodique, tom. i. p. 370.

The ſulphuric acid which is found diſengaged in in ſome places in Italy, appears likewiſe to ariſe from the combuſtion of ſulphur. Baldaſſari has obſerved it in this ſtate in a hollow grotto, in the midſt of a maſs of incruſtations depoſited by the baths of Saint Philip, in Tuſcany. He aſſerts that the ſulphureous vapour continually ariſes in this grotto. He likewiſe found ſulphureous and vitriolic efferveſcences at Saint Albino, near mount Pulciano; and at the lakes of Travale, where he obſerved the branches of a tree covered with concretions of ſulphur and the oil of vitriol.—Journal de Phyſique, t. vii. p. 395.

O. Vandelli relates that, in the environs of Sienna and Viterbo, ſulphuric acid is ſometimes found diſſolved in water. Mr. (the commander) De Dolomieu affirms that he found it pure and cryſtallized in a grotto of mount Etna, from which ſulphur was formerly obtained.

According to a firſt experiment of Mr. Berthollet, ſixty-nine parts of ſulphur with thirty-one parts of oxigene formed one hundred parts of ſulphuric acid; and, according to a ſecond experiment, ſeventy-two of ſulphur and twenty-eight of oxigene formed one hundred parts of dry acid.

The various degrees of concentration of the ſulphuric acid have cauſed it to be diſtinguiſhed by different names, under which it is known in commerce. Hence the denominations of Spirit of Vitriol, Oil of Vitriol, and Glacial Oil of Vitriol, to exprefs its degrees of concentration.

The fulphuric acid is capable of paffing to the concrete ftate by the impreffion of intenfe cold. This congelation is a phenomenon long fince known. Kunckel and Bohn have fpoken of it: and Boerhaave fays exprefsly, "Oleum vitrioli, fumma arte puriffimum, fummo frigore hiberno in glebas folidefcit perfpicuas: fed, ftatim ac acuties frigoris retunditur, liquefcit et diffluit."—We are indebted to the Duke D'Ayen for fome very valuable experiments upon the congelation of this acid; and Mr. De Morveau repeated them with equal fuccefs in 1782, and proved that this congelation may be affected at a degree of cold confiderably lefs than what had been mentioned*.

I have already feveral times obtained beautiful cryftals of fulphuric acid in flattened hexahedral prifms, terminated by an hexahedral pyramid; and my experiments have enabled me to conclude—1. That the very concen-

* See alfo the experiments of Mr. Keir, and the late experiments of Mr. Cavendifh, on the congelation of acids, in the Philofophical Tranfactions.

trated

trated acid cryſtallizes more difficultly than that whoſe denſity lies between ſixty-three and ſixty-five. 2. That the proper degree of cold is from 1 to 3 degrees below 0 of Reaumur. The detail of my experiments may be ſeen in the volume of the Academy of Sciences of Paris for the year 1784.

The characters of the ſulphuric acid are the following.

1. It is unctuous and fat to the touch, which has occaſioned it to obtain the very improper name of Oil of Vitriol.

2. It weighs one ounce and ſeven gros in a bottle containing one ounce of diſtilled water.

3. It produces heat, when mixed with water, to ſuch a degree as to exceed that of boiling water. If one end of a tube of glaſs be cloſed, and water poured into it, and the cloſed end of this tube be plunged into water, the water in the tube may be made to boil by pouring ſulphuric acid into the external water which ſurrounds the tube.

4. It ſeizes with great avidity all inflammable ſubſtances; and it is blackened and decompoſed by this combination.

Stahl ſuppoſed the ſulphuric acid to be the univerſal acid. He founded this opinion more eſpecially upon the circumſtance, that cloths ſoaked in a ſolution of alkali, and expoſed to the air, attracted an acid which combined with the alkali; and formed a neutral ſalt, by him ſuppoſed to be of the nature of ſulphate of pot-aſh, or vitriolated tartar. Subſequent and more accurate experiments have ſhewn that this aërial acid was the carbonic; and the preſent ſtate of our knowledge is ſuch as permits us ſtill leſs than ever to believe in the exiſtence of an univerſal acid.

ARTICLE I.

Sulphate of Pot-aſh.

The ſulphate of pot-aſh is deſcribed indifferently under the names of Arcanum Duplicatum, Sal de Duobus, Vitriolated Tartar, Vitriol of Pot-aſh, &c.

This ſalt cryſtallizes in hexahedral priſms, terminating in hexahedral pyramids, with triangular faces.

It has a lively and penetrating taſte, and melts difficultly in the mouth.

It decrepitates on hot coals, becomes red-hot before it fuſes, and is volatilized without decompoſition.

It is ſoluble in ſixteen parts of cold water, at the temperature of 60 deg. of Fahrenheit; and boiling water diſſolves one-fifth of its weight.

100 grains contain 30.21 acid, 64.61 alkali, and 5.18 water.

Moſt of the ſulphate of pot-aſh uſed in medicine is formed by the direct combination of the ſulphuric acid and pot-aſh, or the vegetable alkali; but that which is met with in commerce is produced in the diſtillation of aqua fortis, by the ſulphuric acid: this has the form of beautiful cryſtals, and is ſold in the Comtat Venaiſin at forty or fifty livres the quintal. The analyſis of tobacco has likewiſe afforded me this ſulphate.

Mr. Baumé proved to the Academy, in 1760, that the nitric acid, aſſiſted by heat, is capable of decompoſing the ſulphate of pot-aſh. Mr. Cornette afterwards ſhewed that the muriatic acid poſſeſſes the ſame virtue; and I ſhewed, in 1780, that this acid may be diſplaced by the nitric acid, without the aſſiſtance of heat; though the ſulphuric acid reſumes its place when the ſolution is concentrated by heat.

ARTICLE II.

Sulphate of Soda.

This combination of the ſulphuric acid and ſoda is ſtill known under the names of Glauber's Salt,

Salt, Sal Admirabile, Vitriol of Soda, &c. This ſalt cryſtallizes in rectangular octahedrons, of a priſmatic or cuneiform figure, of which the two pyramids are truncated near their baſis.

It has a very bitter taſte, and eaſily diſſolves in the mouth.

It ſwells up upon heated coals, and boils, in conſequence of the diſſipation of its water of cryſtallization. After this water has been diſperſed, there remains only a white powder, difficult of fuſion, which is volatilized without decompoſition by a ſtrong heat.

By expoſure to the air, it effervefces, loſes its tranſparency, and is reduced to a fine powder.

Three parts of water, at 60 deg. of Fahrenheit's thermometer, diſſolved one part of this ſalt; but boiling water diſſolves its own weight.

100 grains of ſulphate of ſoda contain 14 acid, 22 alkali, and 64 water.

It is formed by the direct combination of the two principles which contain it; but the tamarix gallica, which grows on the ſea-coaſts, contains ſo large a quantity, that it may be extracted to advantage. Nothing more is neceſſary for this purpoſe, than to burn the plant, and lixiviate the aſhes. That ſalt which is ſold in the ſouth of France, in fine cryſtals, is prepared in this manner. It is very pure, and the price does not exceed thirty or thirty-five livres the quintal. This ſulphate is likewiſe formed in our laboratories when we decompoſe the muriate of ſoda, or common ſalt, by ſulphuric acid.

Pot-aſh diſſolved by heat in a ſolution of ſulphate of ſoda, precipitates the ſoda, and takes its place. See my Chemical Memoirs.

ARTICLE III.

Sulphate of Ammoniac.

The ſulphate of ammoniac, commonly known by the name of Glauber's Secret Ammoniacal Salt, is very bitter.

It cryſtallizes in long flattened priſms with ſix ſides, terminated by ſix-ſided pyramids.

It cannot be obtained in well-formed cryſtals but by inſenſible evaporation.

It ſlightly attracts the humidity of the air.

It liquefies by a gentle heat, and riſes over a moderate fire.

Two parts of cold water diſſolve one of this ſalt; and boiling water its own weight, according to Fourcroy. The fixed alkalis, barytes, and lime, diſengage the ammoniac from it.

The nitric and muriatic acids diſengage the ſulphuric acid.

The

The different ſubſtances of which we have treated are of conſiderable uſe in the arts and medicine.

The ſulphureous acid is employed in whitening ſilk, and giving it a degree of luſtre. Stahl had even combined it with alkali, and formed the ſalt ſo well known under the name of Stahl's Sulphureous Salt. This combination paſſes quickly to the ſtate of ſulphate, if it be left expoſed to the air; as it ſpeedily abſorbs the oxigene which is wanting for that purpoſe.

The principal uſe of the ſulphuric acid is in dyeing, in which art it ſerves to diſſolve indigo, and carry it in a ſtate of extreme diviſion upon the ſtuffs to be dyed; it is likewiſe uſed by the manufacturers of Indiens, or ſilk and ſtuff mixtures, to carry off the preparation of theſe goods, wherein lime is uſed. The chemiſt makes great uſe of this acid in his analyſes; and to ſeparate other acids from their combination, ſuch as the carbonic, the nitric, and the muriatic acids.

The ſulphate of pot-aſh is known in medicine as an alterative, and is uſed in caſes of lacteous coagulations. It is given in the doſe of a few grains, and is even purgative in a greater doſe.

The ſulphate of ſoda is an effectual purgative in the doſe of from four to eight gros, or drams.

drams. For this purpoſe it is diſſolved in a pint of water.

CHAP. III.

Concerning the Nitric Acid.

THE nitric acid, called Aqua Fortis in commerce, is lighter than the ſulphuric. It uſually has a yellow colour, a ſtrong and diſagreeable ſmell, and emits red vapours. It gives a yellow colour to the ſkin, to ſilk, and to almoſt all animal ſubſtances with which it may come in contact. It diſſolves and ſpeedily corrodes iron, copper, zinc, &c. with the eſcape of a cloud of red vapours during the whole time its action laſts. It entirely deſtroys the colour of violets, which it reddens. It unites to water with facility; and the mixture aſſumes a green colour, which diſappears when ſtill further diluted.

This acid has been no where found in a diſengaged ſtate. It always exiſts in a ſtate of combination; and it is from theſe combinations that the art of chemiſtry extracts it, to apply it to our uſes. The nitrate of pot-aſh, or common nitre, is the combination which is beſt known,

known, and is likewiſe that from which we uſually extract the nitric acid.

The proceſs uſed in commerce to make aqua fortis, conſiſts in mixing one part of ſaltpetre with two or three parts of red bolar earth. This mixture is put into coated retorts, diſpoſed in a gallery or long furnace, to each of which is adapted a receiver. The firſt vapour which ariſes in the diſtillation is nothing but water, which is ſuffered to eſcape at the place of juncture, before the luting: and when the red vapours begin to appear, the phlegm which is condenſed in the receiver is poured out; and the receiver, being replaced, is carefully luted to the neck of the retort. The vapours which are condenſed, form at firſt a greeniſh liquor: this colour diſappears inſenſibly, and is replaced by another which is more or leſs yellow. Some chemiſts, more eſpecially Mr. Baumé, were of opinion that the earth acted upon the ſaltpetre by virtue of the ſulphuric acid it contains. But not to mention that this principle does not exiſt in all the earths made uſe of, as Meſſrs. Macquer, De Morveau, and Scheele have proved, we know that pulverized flints equally produce the decompoſition of ſaltpetre. I am therefore of opinion that the effect of theſe earths upon the ſalt ought to be referred to the

very

very evident affinity of the alkali to the ſilex, which is a principal component part; and more eſpecially to the ſlight degree of adheſion which exiſts between the conſtituent principles of nitrate of pot-aſh.

We decompoſe ſaltpetre in our laboratories by means of the ſulphuric acid. Very pure nitrate of pot-aſh is taken, and introduced into a tubulated retort, placed in a ſand bath, with a receiver adapted. All the places of junction are carefully luted; and as much ſulphuric acid as amounts to half the weight of the ſalt is poured through the tubulure; and the diſtillation is proceeded upon. Care is taken to fit a tube into the tubulure of the receiver; the other end of which is plunged into water, to condenſe the vapours, and to remove all fear of an exploſion.

Inſtead of employing the ſulphuric acid, we may ſubſtitute the ſulphate of iron, and mix it with ſaltpetre in equal parts. In this caſe the reſidue of the diſtillation, when well waſhed, forms the mild earth of vitriol made uſe of to poliſh glaſs.

Stahl and Kunckel have ſpoken of a very penetrating aqua fortis, of a blue colour, obtained by the diſtillation of nitre with arſenic.

Whatever precaution is taken in th purification of the ſaltpetre, and however great the attention

attention may be which is beſtowed upon its diſtillation, the nitric acid is always impregnated with ſome foreign acid, either the ſulphuric or muriatic, from which it requires to be purified. It is cleared of the firſt by re-diſtilling it upon very pure ſaltpetre, which retains the ſmall quantity of ſulphuric acid that may exiſt in the mixture. It is deprived of the ſecond by pouring into it a few drops of a ſolution of nitrate of ſilver. The muriatic acid combines with the ſilver, and is precipitated with it in the form of an inſoluble ſalt. The fluid is then ſuffered to remain at reſt, and is afterwards decanted from the precipitate or depoſition. This acid, ſo purified, is known under the name of Aqua Fortis for Parting, Precipitated Nitrous Acid, Pure Nitric Acid, &c.

Stahl had conſidered the nitric acid as a modification of the ſulphuric, produced by its combination with an inflammable principle. This opinion has been ſupported by ſeveral new facts, in a diſſertation of Mr. Pietſh, crowned by the Academy of Berlin in 1749.

The experiments of the celebrated Hales led him ſtill nearer to this concluſion, as his manipulations were ſucceſſively employed upon the two conſtituent principles of the nitric acid. This celebrated philoſopher had obtained ninety

ninety cubic inches of air from half a cubic inch of nitre; and he proceeded no further in his conclufions, than to affert that this air is the principal caufe of the explofions of nitre.

The fame philofopher relates that the pyrites of Walton, treated with equal quantities of fpirit of nitre and water, produce an air which has the property of abforbing the frefh air, which may be made to enter the veffel. This great man, therefore, extracted fucceffively the two principles of the nitric acid; and thefe capital experiments put Dr. Prieftley in the road to the difcoveries he has fince made.

It was not however until the year 1776 that the analyfis of the nitric acid was well known. Mr. Lavoifier, by diftilling this acid from mercury, and receiving the feveral products in the pneumato-chemical apparatus, has proved that the nitric acid, whofe fpecific gravity is to that of diftilled water as 131607 to 100000, contains—

	oz.	gros.	grains.
Nitrous gas	1	7	$51\frac{1}{4}$
Oxigenous gas	1	7	$7\frac{1}{2}$
Water	13	—	—

By combining thefe three principles together the decompofed acid was regenerated.

The action of the nitric acid on moft inflammable

mable matters, consists in nothing more than a continual decomposition of this acid.

If the nitric acid be poured upon iron, copper, or zinc, these metals are instantly attacked with a strong effervescence; and a considerable disengagement of vapours takes place, which become of a red colour by their combination with the atmospheric air, but which may be retained and collected in the state of gas in the hydro-pneumatic apparatus. In all these cases the metals are strongly oxided.

The nitric acid, when mixed with oils, renders them thick and black, converts them into charcoal, or inflames them, accordingly as the acid is more or less concentrated, or in a greater or less quantity.

If very concentrated nitric acid be put into an apothecary's phial, and be poured upon charcoal in an impalpable powder, and very dry, it sets it on fire instantly, at the same time that carbonic acid and nitrogene gas are disengaged.

The various acids which are obtained by the digestion of the nitric acid on certain substances, such as the oxalic acid, or acid of sugar, the arsenical acid, &c. owe their existence merely to the decomposition of the nitric acid, the oxigene of which is fixed in combination

with

with the bodies upon which this acid is decomposed, renders it one of the most active; because the action of acids upon most bodies is a consequence of their own proper decomposition.

The characters of nitrous gas, which is extracted by the decomposition of the acid, are— 1. It is invisible, or perfectly transparent. 2. Its specific gravity is rather less than that of atmospherical air. 3. It is unfit for respiration, though the abbé Fontana pretends that he respired it without danger. 4. It does not maintain combustion. 5. It is not acid, according to the experiments of the Duke de Chaulnes. 6. It combines with oxigene, and reproduces the nitric acid.

But what is the nature of this nitrous gas? It was at first pretended that it consists of the nitric acid saturated with phlogiston. This system ought to have been abandoned as soon as it was proved that the nitric acid deposited its oxigene upon the bodies on which it acted; and that the nitrous gas was less in weight than the acid made use of. A capital experiment of Mr. Cavendish has thrown the greatest light on the subject. This chemist having introduced into a tube of glass seven parts

parts of oxigenous gas obtained without nitrous acid, and three parts of nitrogene gas; or, by eſtimating theſe quantities in weight, ten parts of nitrogene to twenty-ſix of oxigene—and having cauſed the electric ſpark to paſs through this mixture, perceived that its volume or bulk was greatly diminiſhed, and ſucceeded in converting it into nitric acid. It may be preſumed, from his experiment, that the acid is a combination of ſeven parts of oxigene, and three of nitrogene. Theſe proportions conſtitute the ordinary nitric acid; but when a portion of its oxigene is taken away, it paſſes to the ſtate of nitrous gas; ſo that nitrous gas is a combination of nitrogene gas, with a ſmall quantity of oxigene.

Nitrous gas may be decompoſed by expoſing it to a ſolution of the ſulphure of pot-aſh, or hepar of ſulphur: the oxigene gas unites to the ſulphur, and forms ſulphuric acid; while the nitrogene gas remains behind in a ſtate of purity.

Nitrous gas may likewiſe be decompoſed by means of pyrophorus, which burns in this air, and abſorbs the oxigenous gas.

The electric ſpark has likewiſe the property of decompoſing nitrous gas. Mr. Van Marum has obſerved that three cubic inches of the ni-

trous

trous gas are reduced by electricity to one cubic inch and three quarters; and that this residue no longer poſſeſſed any property of nitrous gas. Laſtly, according to the experiments of Mr. Lavoiſier, one hundred grains of nitrous gas contain thirty-two parts nitrogene, and ſixty-eight parts oxigene: according to the ſame chemiſt, one hundred grains of nitric acid contain ſeventy-nine and a half oxigene and twenty and a half nitrogene; and this is the reaſon why nitrous gas ſhould be employed in a leſs portion than nitrogene gas, to combine with the oxigene gas, and form the nitric acid.

Theſe ideas upon the compoſition of the nitrous acid, appear to be confirmed by the repeated proofs we now have of the neceſſity of cauſing ſubſtances, which afford much nitrogene gas, to be preſented to the oxigene gas, in order to obtain nitric acid.

The ſeveral ſtates of the nitric acid may be clearly explained according to this theory:— 1. The fuming nitrous acid is that in which the oxigene does not exiſt in a ſufficient proportion; and we may render the whiteſt and the moſt ſaturated nitric acid fuming and ruddy, by depriving it of a part of its oxigene by means of metals, oils, inflammable ſubſtances, &c. or even by diſengaging the oxigene by the ſimple expoſition of the acid to the light of the ſun, according to the valuable experiments of Mr. Berthollet.

The property which nitrous gas poſſeſſes, of abſorbing oxigene to form the nitric acid, has cauſed it to be employed to determine the proportion of oxigene in the compoſition which forms our atmoſphere. The abbé Fontana has conſtructed, on theſe principles, an ingenious eudiometer, the deſcription and manner of uſing which may be ſeen in the firſt volume of Dr. Ingenhouſz's Experiments upon Vegetables.

Mr. Berthollet has very juſtly obſerved, that this eudiometer is inaccurate, or productive of deception—1. Becauſe it is difficult to obtain nitrous gas conſtantly formed of the ſame proportions of nitrogene gas and oxigene; for they vary, not only according to the nature of the ſubſtances upon which the nitric acid is decompoſed, but likewiſe accordingly as the ſolution of any given ſubſtance by the acid is made with greater or leſs rapidity. If the acid be decompoſed upon a volatile oil, nothing but nitrogene gas can be obtained; if the acid act upon iron, and it be much concentrated, nitrogene gas only will be obtained, as I have obſerved, &c. 2. The nitric acid which is formed by the union of nitrous gas and oxigene, diſſolves a greater or leſs quantity of nitrous gas according to the temperature, the quality of the air which is tried, the ſize of the eudiometer, &c. ſo that the diminution varies in proportion to the greater or leſs quantity of nitrous gas obtained by the nitric acid which is formed : conſequently the diminution ought to be greater in winter than in ſummer, &c.

According to the experiments of Mr. Lavoiſier, four parts of oxigenous gas are ſufficient to ſaturate ſeven parts and one-third of nitrous gas ; whereas it is found that nearly ſixteen parts of atmoſpheric air are required to produce the ſame effect : whence this celebrated chemiſt has concluded, that the air of the atmoſphere does not in general contain more than one-fourth of oxigenous or reſpirable gas. Repeated experiments at Montpellier, upon the ſame principle, have convinced me that twelve or thirteen parts of atmoſpheric air are conſtantly ſufficient to ſaturate ſeven parts and one-third of nitrous gas.

Theſe experiments ſhew, to a certain degree of accuracy, the proportion in which vital air exiſts in the air which we reſpire ; but they do not give us any information reſpecting the noxious gaſes which, when mixed with the atmoſpheric air, alter it, and render it unwholſome.

This obſervation very much curtails the uſe of this inſtrument.

The combination of the oxigenous and nitrous gaſes always leaves an aëriform reſidue, which Mr. Lavoiſier eſtimated at about one thirty-fourth of the whole volume: it ariſes from the mixture of the foreign gaſeous ſubſtances, which more or leſs affect the purity of the gaſes made uſe of.

ARTICLE I.

Nitrate of Pot-aſh.

The nitric acid, combined with pot-aſh, forms the ſalt ſo well known under the names of Nitre, Saltpetre, Nitre of Pot-aſh, &c.

This neutral ſalt is rarely the product of any direct combination of its two conſtituent parts. It is found ready formed in certain places; and in this manner it is that the whole of the nitre employed in the arts is obtained.

In the Indies, it effloreſces on the ſurface of uncultivated grounds. The inhabitants lixiviate theſe earths with water, which they afterwards boil and cryſtallize in earthen pots. Mr. Dombey has obſerved a great quantity of ſaltpetre near Lima, upon earths which ſerve for

paſture,

paſture, and which produce only gramineous plants. Mr. Talbot Dillon, in his travels into Spain, relates that one-third of all the grounds, and in the ſouthern parts of that kingdom even the duſt of the roads, contain ſaltpetre.

Saltpetre is extracted in France from the ruins and plaſter of old houſes.

This ſalt exiſts ready formed in vegetables, ſuch as parietaria and bugloſs, &c. And one of my pupils, Mr. Virenque, has proved that it is produced in all extracts which are capable of fermenting.

The fermentation of ſaltpetre may be favoured, by cauſing certain circumſtances to concur which are of advantage to its formation.

In the north of Europe, the ſaltpetre-beds are formed with lime, aſhes, earth of uncultivated grounds, and ſtraw, which are ſtratified, and watered with urine, dunghill-water, and mother waters. Theſe beds are defended by a covering of heath or broom. In the year 1775, the King cauſed a prize to be propoſed by the Royal Academy of Sciences at Paris, to diſcover a method of increaſing the product of ſaltpetre in France, and to relieve the people from the obligation of permitting the ſaltpetre makers to examine their cellars, in order to diſcover and carry away ſaltpetre earths. Several Me-

moir

moirs were offered on the subject, which the Academy united into a single volume; and these have added to our knowledge, by instructing us more especially concerning the nature of the matters which favour the formation of nitre. It was known, for example, long since, that nitre is formed in preference near habitations, or in earths, impregnated with animal products: it was likewise known that, in general, the alkaline basis was afforded by the concurrence of a vegetable fermentation. Mr. Thouvenel, whose Memoir was crowned, has proved that the gas which is disengaged by putrefaction, is necessary for the formation of nitre; that blood, and, next to it, urine, were the animal parts which were the most favourable to its formation; that the most minutely divided and the lightest earths were the most proper for nitrification; that the current of air must be properly managed, to fix upon these earths the nitric acid which is formed, &c.

It seems to me that Becher possessed a considerably accurate knowledge of the formation of nitre, as appears from the following passages:

"Hæc enim (vermes, muscæ, serpentes) putrefacta in terram abeunt prorsus nitrosam; ex qua etiam communi modo nitrum copiosum parari potest, sola elixatione cum aqua communi."—Phys. Subt. lib. i. S. V. t. i. p. 286.

"Sed

" Sed et ipsum nitrum necdum finis ultimus " putrefactionis est; nam cum ejusdem partes " igneæ separantur, reliquæ in terram abeunt " prorsum puram et insipidam, sed singulari " magnetismo præditam novum spiritum aëre- " um attrahendi, rursusque nitrum fiendi."— Phys. Subt. S. V. t. i. p. 292.

From all the discoveries and observations which have been hitherto made, it follows that, in order to establish artificial nitre beds, it is necessary that animal putrefaction and vegetable fermentation should concur. The nitrogene gas, in its disengagement from the animal substances, combines with the oxigene, and forms the acid, which again unites with the alkali, whose formation is favoured by the vegetable decomposition.

When the manufacturer is in possession of salt-petre grounds, whether by the simple operations of nature or by the assistance of art, the saltpetre is extracted by the lixiviation of these earths; which lixivium is afterwards concentrated, and made to crystallize. In proportion as the evaporation goes forward, the marine salt, which almost always accompanies the formation of nitre, is precipitated. This is taken out with ladles, and set to drain in baskets placed over the boilers.

As a great part of the nitre has an earthy basis, and requires to be furnished with an alkaline basis to cause it to crystallize, this purpose is accomplished either by mixing ashes with the saltpetre earths, or by adding an alkali ready formed to the lixivium itself.

Nitre obtained by this first operation is never pure, but contains sea-salt, and an extractive and colouring principle, from which it must be cleared. For this purpose it is dissolved in fresh water, which is evaporated; and to which bullocks blood may be added, to clarify the solution. The nitre obtained by the second manipulation is known by the name of Nitre of the Second Boiling. If recourse be had to a third operation to purify it, it is then called Nitre of the Third Boiling.

The purified nitrate of pot-ash is employed in delicate operations, such as the manufacture of gunpowder, the preparation of aqua fortis for parting, and the solution of mercury, &c. The saltpetre of the first boiling is used in those works where aqua fortis is made for the dyers. It affords a nitro-muriatic acid, which is capaple of dissolving tin by itself.

The nitrate of pot-ash crystallizes in prismatic octahedrons, which almost always represent six-sided flattened prisms, terminated by dihedral summits.

It

It has a penetrating tafte, followed by a fenfation of coldnefs.

It is fufible upon ignited coals; and in this cafe its acid is decompofed. The oxigene unites with the carbone, and forms the carbonic acid; the nitrogene gas and the water are diffipated; and it is this mixture of principles which has been known under the name of Clyffus of Nitre.

The diftillation of the nitrate of pot-afh affords twelve thoufand cubic inches of oxigenous gas for each pound of the falt.

Seven parts of water diffolve one of nitre, at fixty degrees of Fahrenheit; and boiling water diffolves its own weight of this falt.

One hundred grains of the cryftals of nitre contain thirty acid, fixty-three alkali, and feven water.

When a mixture of equal parts of nitre and fulphur is thrown into a red-hot crucible, a faline fubftance is obtained, which was formerly called Sal Polychreft of Glafer, and which has fince been confidered as Sulphate of Pot-afh. If nitre be fufed, and a few pinches of fulphur be thrown upon this falt in fufion, and the whole be afterwards poured out or caft into plates, it forms a falt known by the name of Cryftal Mineral.

A mixture

A mixture of seventy-five parts of nitre, nine and a half of sulphur, and fifteen and a half of charcoal, forms gunpowder. This mixture is triturated from ten to fifteen hours, care being taken to moisten it from time to time. This trituration is usually performed by pounding mills, whose pestles and mortars are of wood. In order to give the powder the form proper to granulate it, it is passed through sieves of skin, whose perforations are of various sizes. The grained powder is then sifted, to separate the dust, and it is afterwards carried to the drying-house. Gunpowder for artillery, or cannon-powder, receives no other preparation; but it is necessary to glaze the powder which is intended for fowling. This last preparation is effected by putting it into a kind of cask which turns on an axis, and by whose movement the angles of the grains are broken, and their surfaces polished. We are indebted to Mr. Baumé and the chevalier Darcy for a series of experiments, in which they have proved—

1. That good gunpowder cannot be made without sulphur.

2. That charcoal is likewise indispensably necessary.

3. That the quality of gunpowder depends, cæteris paribus, upon the accuracy with which the mixture is made.

4. That the effect of powder is greater when ſimply dried than when it is granulated.

The effect of gunpowder depends upon the rapid decompoſition which is made in an inſtant of a conſiderable maſs of nitre, and the ſudden formation of thoſe gaſes which are the immediate product. Bernoulli, in the laſt century, aſcertained the development of air by the deflagration of gunpowder: he placed four grains of powder in a recurved tube of glaſs, plunged the tube in water, and ſet fire to the gunpowder by means of the burning-glaſs; after the combuſtion the interior air occupied a larger ſpace, ſo that the ſpace abandoned by the water was ſuch as would have contained two hundred grains of gunpowder.—Hiſt. de l'Académie des Sciences de Paris, 1696, t. ii. Mémoire de M. Varignon ſur le Feu et la Flamme.

The fulminating powder, which is made by the mixture and trituration of three parts of nitre, two of ſalt of tartar, and one of ſulphur, produces effects ſtill more terrible. In order to obtain the full effect, it is expoſed in a ladle to a gentle heat; the mixture melts, a ſulphureous blue flame appears, and the exploſion takes place. Care muſt be taken to give neither too ſtrong nor too ſlight a degree of heat. In either caſe, the combuſtion of the principles takes place ſeparately, and without exploſion.

ARTI-

ARTICLE II.

Nitrate of Soda.

This ſalt has received the name of Cubic Nitre, on account of its form; but this denomination is not exact, becauſe it affects a figure conſtantly rhomboidal.

It has a cool, bitter taſte.

It ſlightly attracts the humidity of the air.

Cold water, at ſixty degrees of Fahrenheit's thermometer, diſſolves one-third of its weight; and hot water ſcarcely diſſolves more.

It fuſes upon burning coals with a yellow colour; whereas common nitre affords a white flame, according to Margraff—24 Diſſert. ſur le Sel Commun, t. ii. p. 343.

100 grains of this ſalt contain 28.80 acid, 50.09 alkali, and 21.11 water.

It is almoſt always the product of art.

ARTICLE III.

Nitrate of Ammoniac.

The vapours of ammoniac, or volatile alkali, being brought into contact with thoſe of the nitrous

nitrous acid, combine with them, and form a white and thick cloud, which ſlowly ſubſides.

But when the acid is directly united to the alkali, the reſult is a ſalt, which has a cool, bitter, and urinous taſte.

Mr. De Liſle pretends that it cryſtallizes in beautiful needles, ſimilar to thoſe of ſulphate of pot-aſh.

Theſe cryſtals cannot be obtained but by a very ſlow evaporation.

When this ſalt is expoſed to the fire, it liquefies, emits aqueous vapours, dries, and detonates.

Mr. Berthollet has analyſed all the reſults of this operation, and has drawn from them a new proof of the truth of the principles which he has eſtabliſhed with regard to ammoniac.

CHAP. IV.

Concerning the Muriatic Acid.

THIS acid is generally known by the name of Marine Acid, and it is ſtill diſtinguiſhed among artiſans by the name of Spirit of Salt.

It is lighter than the two preceding acids; it has

has a ſtrong penetrating ſmell, reſembling that of ſaffron, but infinitely more pungent; it emits white vapours when it is concentrated; it precipitates ſilver from its ſolution in the form of an inſoluble ſalt, &c. This acid has no where been found diſengaged; and, to obtain it in this ſtate, it is neceſſary to diſengage it from its combinations. Common ſalt is uſually employed for this purpoſe.

The ſpirit of ſalt of commerce is obtained by a proceſs little differing from that which is uſed in the extraction of aqua fortis. But as this acid adheres more ſtrongly to its baſis, the product is very weak, and only part of the marine ſalt is decompoſed.

Flints pulverized, and mixed with this ſalt, do not ſeparate the acid. Ten pounds of flints in powder, treated by a violent fire with two pounds of the ſalt, did not afford me any other product than a maſs of the colour of litharge. The fumes were not perceptibly acid. If clay, which has once ſerved to decompoſe marine ſalt, be mixed with a new quantity of the ſame ſalt, it will not decompoſe an atom of it, even though the mixture be moiſtened and formed into a paſte. Theſe experiments have been ſeveral times repeated in my manufactory, and have conſtantly exhibited the ſame reſults.

The

The sulphate of iron, or martial vitriol, which so easily disengages the nitric acid, decomposes marine salt; but very imperfectly.

The impure soda known in France by the name of Blanquette, and in which my analysis has exhibited twenty-one pounds of common salt out of twenty-five, scarcely affords any muriatic acid when it is distilled with the sulphuric acid; but it affords abundance of sulphureous acid. Mr. Berard, director of my manufactory, attributed these results to the coal contained in this soda, which decomposed the sulphuric acid. He therefore calcined the blanquette to destroy the charcoal; and then he found he could treat it in the same manner as common salt, and with the same success.

The sulphuric acid is usually employed to decompose marine salt. My method of proceeding consists in drying the marine salt, pounding it, and putting it into a tubulated retort placed upon a sand bath. A receiver is adapted to the retort, and afterwards two bottles, after the manner of Woulfe, in which I distribute a weight of distilled water equal to that of the marine salt made use of. The joinings of the vessels are then luted, but with the greatest caution; and when the apparatus is thus fitted up, a quantity of sulphuric acid is

poured

poured through the tubulure equal to half the weight of the ſalt. A conſiderable ebullition is immediately excited; and when this efferveſcence is ſlackened, the retort is gradually heated, and the mixture made to boil.

The acid is diſengaged in the ſtate of gas; and mixes rapidly with the water, in which it produces a conſiderable degree of heat.

The water of the firſt bottle is uſually ſaturated with the acid gas, and forms a very concentrated and fuming acid; and though the ſecond is weaker, it may be carried to any deſired degree of concentration, by impregnating it with a new quantity of the gas.

The ancient chemiſts were divided reſpecting the nature of the muriatic acid. Becher ſuppoſed it to be the ſulphuric acid modified by his mercurial earth.

This acid is ſuſceptible of combining with an additional doſe of oxigene; and, what is very extraordinary, it becomes more volatile in conſequence of this additional quantity; whereas the other acids appear to acquire a greater degree of fixity in the ſame circumſtances. It may even be ſaid, that its acid virtues become weaker in this caſe, ſince its affinities with alkalis diminiſh; and it is ſo far from reddening blue vegetable colours, that it deſtroys them.

Another

Another phenomenon not lefs interefting, which is prefented to us by this new combination, is, that though the muriatic acid feizes the oxigene with avidity, yet it contracts fo weak a union with it, that it yields it to almoft all bodies, and the mere action of light alone is fufficient to difengage it.

It is to Scheele that we are indebted for the difcovery of the oxigenated muriatic acid. He formed it in the year 1774, by employing the muriatic acid as a folvent for manganefe. He perceived that a gas was difengaged, which poffeffed the diftinctive fmell of aqua regia; and he was of opinion that in this cafe the muriaric acid abandoned its phlogifton to the manganefe; in confequence of which notion he called it the Dephlogifticated Marine Acid. He took notice of the principal and truly aftonifhing properties of this new fubftance; and all chemifts fince his time have thought their attention well employed in examining a fubftance which exhibits fuch fingular properties.

To extract this acid, I place a large glafs alembic of one fingle piece upon a fand bath. To the alembic I adapt a fmall receiver; and to the receiver three or four fmall bottles nearly filled with diftilled water, and arranged according to the method of Woulfe. I difpofe the receiver and the bottles in a ciſtern, the places of junction being luted with fat lute, and ſecured with rags ſoaked in the lute of lime and white of egg. Laſtly, I ſurround the bottles with pounded ice. When the apparatus is thus diſpoſed, I introduce into the alembic half a pound of manganeſe of Cevennes, and pour upon it, at ſeveral repetitions, three pounds of fuming muriatic acid. The quantity of acid which I pour at once is three ounces; and at each time of pouring a conſiderable effervеſcence is excited. I do not pour a new quantity until nothing more comes over into the receivers. This method of proceeding is indiſpenſably neceſſary, when the operator is deſirous of making his proceſs with a definite quantity of the materials. For if too large a quantity of acid be poured at once, it is impoſſible to reſtrain the vapours; and the effervеſcence will throw a portion of the manganeſe into the receiver. The vapours which are developed by the affuſion of muriatic acid are of a greeniſh yellow colour; and they communicate this colour to the water when they combine with it. When this vapour is concentrated by means of the ice, and the water is ſaturated with it, it forms a ſcum at the ſurface, which is precipitated through the liquid, and reſembles a congealed oil.

oil. It is neceſſary to aſſiſt the action of the muriatic acid by means of a moderate heat applied to the ſand bath. The ſecure luting of the veſſels is alſo an eſſential circumſtance; for the vapour which might eſcape is ſuffocating, and would not permit the chemiſt to inſpect his operation cloſely. It is eaſy to diſcover the place where it eſcapes through the lutes, by running a feather dipped in volatile alkali over them: the combination of theſe vapours inſtantly forms a white cloud, which renders the place viſible where the vapour eſcapes. An excellent Memoir of Mr. Berthollet, publiſhed in the Annales Chimiques, may be conſulted upon the oxigenated muriatic acid.

The ſame oxigenated muriatic acid may be obtained by diſtilling, in a ſimilar apparatus, ten pounds of marine ſalt, three or four pounds of manganeſe, and ten pounds of ſulphuric acid.

Mr. Reboul has obſerved that the concrete ſtate of this acid is a cryſtallization of the acid, which takes place at three degrees of temperature below the freezing point of Reaumur. The forms which have been obſerved are thoſe of a quadrangular priſm, truncated very obliquely, and terminated by a lozenge. He has likewiſe obſerved hollow hexahedral pyramids on the ſurface of the liquor.

To make uſe of the oxigenated acid in the arts, and in order to concentrate a greater quantity in a given volume of water, the vapour is made to paſs through a ſolution of alkali. A white precipitate is at firſt formed in the liquor; but a ſhort time afterwards the depoſition diminiſhes, and bubbles are diſengaged, which are nothing but the carbonic acid. In this caſe two ſalts are formed, the oxigenated muriate, and the ordinary muriate. The mere impreſſion of light is ſufficient to decompoſe the former, and convert it into common ſalt. This lixivium contains, indeed, the oxigenated acid in a ſtronger proportion. The execrable ſmell of the acid is much weakened. It may be employed for various uſes with the ſame ſucceſs, and with great facility; but the effect is very far from correſponding with the quantity of oxigenated acid which enters into this combination, becauſe the virtue of a great part is deſtroyed by its union with the alkaline baſis.

The oxigenated muriatic acid has an exceſſively ſtrong ſmell. It acts directly on the larynx, which it ſtimulates, excites coughing, and produces violent head-aches.

Its taſte is ſharp and bitter. It ſpeedily deſtroys the colour of tincture of turnſole. But it appears that the property which moſt oxigenated

nated ſubſtances poſſeſs, of reddening blue colours, ariſes only from the combination of oxigene with the colouring principles; and that, when this combination is very ſtrong and rapid, the colour is deſtroyed.

The oxigenated muriatic acid with which a ſolution of cauſtic alkali is ſaturated, affords, by evaporation in veſſels ſecluded from the light, common muriate and oxigenated muriate. This laſt detonates upon charcoal; is more ſoluble in hot than in cold water; cryſtallizes, ſometimes in hexahedral laminæ, and oftener in rhomboidal plates. Theſe cryſtals have an argentine brilliancy, like mica. Its taſte is faint; and its cryſtals, when they are diſſolved in the mouth, produce a ſenſation of coolneſs reſembling that of nitre.

Mr. Berthollet has aſcertained, by delicate experiments, that the oxigenated muriatic acid which exiſts in the oxigenated muriate of potaſh, contains more oxigene than an equal weight of oxigenated muriatic acid diſſolved in water; and this has led him to conſider the oxigenated acid combined in the muriate as being ſuperoxigenated. He conſiders the common muriatic gas with relation to the oxigenated muriatic gas, the ſame as the nitrous gas or ſulphureous gas with reſpect to the nitric and ſulphuric

acids,

acids. He pretends that the production of the ſimple muriate and the oxigenated muriate in the ſame operation, may be compared to the action of the nitric acid, which in many caſes produces nitrate and nitrous gas. Hence he has conſidered the muriatic acid as a pure radical, which combined with a greater or leſs quantity of oxigene, forms either ſimple muriatic acid gas, or the oxigenated muriatic acid gas.

The oxigenated muriates of ſoda do not differ from thoſe of pot-aſh, but in being more deliqueſcent and ſoluble in alcohol, like all the ſalts of this nature.

The oxigenated muriate of pot-aſh gives out its oxigene in the light, and by diſtillation as ſoon as the veſſel is heated to redneſs. One hundred grains of this ſalt afford ſeventy-five cubic inches of oxigenous gas reduced to the temperature of twelve degrees of Reaumur. This air is purer than the others, and may be employed for delicate experiments. The oxigenated muriate of pot-aſh, when cryſtallized, does not trouble the ſolutions of nitrate of lead, of ſilver, or of mercury.

Mr. Berthollet has fabricated gunpowder, by ſubſtituting the oxigenated muriate inſtead of ſaltpetre. The effects it produced were quadruple. The experiment in the large way, which

which was made at Effone, is but too well known, by the death of Mr. Le Tors and Mademoifelle Chevraud. This powder exploded the moment the mixture was triturated.

The oxigenated muriatic acid whitens thread and cotton. For this purpofe the cotton is boiled in a weak alkaline lixivium; after which the ftuff is wrung out, and fteeped in the oxigenated acid. Care is taken to move the cloth occafionally in the fluid, and to wring it out. It is then wafhed in a large quantity of water, to deprive it of the fmell with which it is impregnated.

I have applied this known property to the whitening of paper and old prints: by this means they obtained a whitenefs which they never before poffeffed. Common ink difappears by this acid; but printers ink is not attacked by it.

Linen and cotton cloths, and paper, may be bleached by the vapour of the oxigenated marine acid. I have made fome experiments in the large way, which have convinced me of the poffibility of applying this method to the arts. The Memoir in which I have given an account of my experiments, will be printed in the volume of the Academy of Paris for the year 1787.

The oxigenated muriatic acid thickens oils;

and

and oxides metals to ſuch a degree, that this proceſs may be advantageouſly uſed to form verditer.

The oxigenated muriatic acid diſſolves metals without efferveſcence; becauſe its oxigene is ſufficient to oxide them without the neceſſity of the decompoſition of water, and conſequently without the diſengagement of gas.

This acid precipitates mercury from its ſolution, and converts it into the ſtate of corroſive ſublimate.

It converts ſulphur into ſulphuric acid, and inſtantly deprives the very black ſulphuric acid of its colour.

When mixed with nitrous gas, it paſſes to the ſtate of muriatic acid, and converts part of the gas into nitric acid.

When expoſed to light, it affords oxigenous gas, and the muriatic acid is regenerated.

The muriatic acid acts very efficaciouſly upon metallic oxides, merely in conſequence of its becoming oxigenated; and in this caſe it forms with them ſalts, which are likewiſe more or leſs oxigenated.

ARTI-

ARTICLE I.

Muriate of Pot-aſh.

This ſalt is ſtill diſtinguiſhed by the name of Febrifuge Salt of Sylvius.

It has a diſagreeable ſtrong bitter taſte.

It cryſtallizes in cubes, or in tetrahedral priſms.

It decrepitates upon coals; and when urged by a violent heat it fuſes, and is volatilized without decompoſition.

It requires three times its weight of water, at the temperature of ſixty degrees of Fahrenheit, for its ſolution.

It is ſubject to little alteration in the air.

One hundred grains of this ſalt contain 29.68 acid, 63.47 alkali, and 6.85 water. It is frequently met with, but in ſmall quantities, in the water of the ſea, in plaſter, in the aſhes of tobacco, &c. The exiſtence of this ſalt in the aſhes of tobacco might with juſtice have ſurpriſed me, as I had reaſon to expect the muriate of ſoda which is employed in the operation called watering. Was the ſoda metamorphoſed into pot-aſh by the vegetable fermentation? This may be determined by direct experiments.

ARTI-

ARTICLE II.

Muriate of Soda.

The received names of Marine Salt, Common Salt, and Culinary Salt, denote the combination of muriatic acid with ſoda.

This ſalt has a penetrating but not bitter taſte. It decrepitates on coals, fuſes, and is volatilized by the heat of a glaſs-maker's furnace, without decompoſition.

It is ſoluble in 2.5 times its weight of water, at ſixty degrees of Fahrenheit's thermometer.

One hundred grains of this ſalt contain 33.3 acid, 50 of alkali, and 16.7 of water.

It cryſtallizes in cubes. Mr. Gmelin has informed us that the ſalt of the ſalt lakes in the environs of Sellian on the banks of the Caſpian ſea, forms cubical and rhomboidal cryſtals.

Mr. De Liſle obſerves, that a ſolution of marine ſalt, left to inſenſible evaporation during five years by Mr. Rouelle, had formed regular octahedral cryſtals reſembling thoſe of alum.

Marine ſalt may be obtained in octahedrons, by pouring freſh urine into a very pure ſolution of freſh ſalt. Mr. Berniard is convinced that this addition changed only the form of the ſalt, without altering its nature.

Common

Common ſalt is found native in many places. Catalonia, Calabria, Switzerland, Hungary, and Tyrol poſſeſs mines, which are more or leſs abundant. The richeſt ſalt mines are thoſe of Wieliczka in Poland. Mr. Berniard has given us a deſcription of them in the Journal de Phyſique; and Mr. Macquart, in his Eſſays on Mineralogy, has added intereſting details concerning the working of theſe mines.

Our ſalt ſprings in Lorraine and Franche-comté, and ſome indications afforded by Bleton, have appeared ſufficient motives to Mr. Thouvenel to preſume that ſalt mines exiſt in our kingdom. This chemiſt expreſſes himſelf in the following manner:

" At the diſtance of two leagues from Saverne, between the village of Hučtenhauſen and that of Garbourg, in a lofty mountain called Penſenperch, there are two great reſervoirs of ſalt water; the one to the eaſt, at the head of a large deep and narrow valley, which is called the great Limerthaal; the other to the weſt, upon the oppoſite ſlope, towards Garbourg. They communicate together by five ſmall ſtreams, which are detached from the upper reſervoir, and unite in the lower one. From theſe two ſalt reſervoirs flow two large ſtreams; the upper runs into Franche-comté, and the lower into

into Lorraine, where they supply the well-known salt works."

The waters therefore flow to the distance of seventy leagues from the reservoir.

Salt mines appear to owe their origin to the drying up of vast lakes. The shells and madrepores found in the immense mines of Poland are proofs of marine depositions. There are likewise some seas in which the salt is so abundant, that it is deposited at the bottom of the water; as appears from the analysis of the water of the lake Asphaltites, made by Messrs. Macquer and Sage.

This native salt is often coloured; and as in this state it possesses considerable brilliancy, it is called Sal-gem. It almost always contains an oxide of iron, which colours it.

As these salt mines are neither sufficiently abundant to supply the wants of the inhabitants of the globe, nor distributed with that uniformity as to permit all nations to have ready recourse to them, it has been found necessary to extract the salt from the water of the sea. The sea does not contain an equal quantity in all climates; Ingenhousz has shewn us that the northern seas contain less than the southern. Marine salt is so abundant in Egypt, that, according to Hasselquist, a fresh-water spring is

a treasure

a treaſure which is ſecretly tranſmitted from father to ſon.

The method of extracting the water of the ſea varies according to the climates.

1. In the northern provinces, the ſalt ſands of the ſea coaſts are waſhed with the leaſt poſſible quantity of water, and the ſalt is obtained by evaporation.—See the deſcription of this proceſs by Mr. Guettard.

2. In very cold countries, ſalt water is concentrated by freezing, and the reſidue is evaporated by fire.—See Wallerius.

3. At the ſalt ſprings of Lorraine and Franchecomté, the water is pumped up, and ſuffered to fall upon heaps of thorns, which divide it, and cauſe a part to evaporate. The farther concentration is effected in boilers.

4. In the ſouthern provinces, at Peccais, at Peyrat, at Cette, and elſewhere, the extraction is begun by ſeparating a certain quantity of water from the general maſs of the ſea, which is ſuffered to remain in ſquare ſpaces, called Partenemens. For this purpoſe it is neceſſary to have ſluices which may be opened and ſhut at pleaſure, and to form ſurrounding walls which prevent all communication with the ſea, except by means of theſe gates. It is in the partenemens that the water goes through the firſt

firſt ſtage of evaporation; and when it begins to depoſit its ſalt, it is raiſed by bucket wheels to other ſquare compartments, called Tables, where the evaporation finiſhes.

The ſalt is heaped together, to form the *cammelles;* in which ſtate it is left for three years, in order that the deliqueſcent ſalts may flow out of it; and, after this interval of time, it is carried to market.

Exertions and enquiries have long ſince been made to diſcover a cheap method of decompoſing marine ſalt, to obtain the mineral alkali at a low price, which is of ſuch extenſive uſe in the manufactures of ſoap, glaſs, bleaching, &c. The proceſſes hitherto diſcovered are the following:

1. The nitric acid diſengages the muriatic acid, and forms the nitrate of ſoda, which may be eaſily decompoſed by detonation.

2. Pot-aſh diſplaces the ſoda, even in the cold, as I found by experiment.

3. The ſulphuric acid forms ſulphate of ſoda by decompoſing the marine ſalt; the new ſalt, when heated with charcoal, is deſtroyed; but a ſulphure of ſoda, or liver of ſulphur, is formed, which is difficult to be entirely ſeparated; and this proceſs does not appear to me to be economical. The ſulphate may likewiſe be decompoſed

pofed by the acetite of barytes, and the foda afterwards obtained by calcination of the acetite of foda.

4. Margraff tried in vain to accomplifh this purpofe, by means of lime, ferpentine, iron, clay, &c. He adds that if common falt be thrown upon lead heated to rednefs, the falt is decompofed, and muriate of lead is formed.

5. Scheele has pointed out the oxides of lead for the decompofition of common falt. If common falt be mixed with litharge, and made into a pafte, the litharge gradually lofes its colour, and becomes converted into a white matter, from which the foda may be extracted by wafhing. It is by proceffes of this kind that Turner extracts it in England; but this decompofition never appeared to me to be complete, unlefs the litharge was employed in a proportion quadruple to that of the falt. I have obferved that almoft all the bodies are capable of alkalizing marine falt, but that the abfolute decompofition is very difficult.

6. Barytes decompofes it likewife, according to the experiments of Bergmann.

7. The vegetable acids, combined with lead, may likewife be ufed to decompofe common falt. When thefe falts are mixed, a decompofition takes place: the muriate of lead falls down;

down; and the vegetable acid, united to the ſoda, remains in ſolution. The vegetable acid may be diſſipated by evaporation and calcination; and the alkali remains diſengaged.

Marine ſalt is more eſpecially employed at our tables, and in culinary purpoſes. It removes and corrects the inſipidy of our food, and at the ſame time facilitates digeſtion. It is uſed in a large proportion to preſerve fleſh from putrefaction; but in a ſmall doſe it haſtens that proceſs, according to the experiments of Pringle, Macbride, Gardane, &c.

ARTICLE III.

Muriate of Ammoniac.

Of all the combinations of ammoniac this is the moſt intereſting, and the moſt generally uſed. It is known by the name of Sal Ammoniac.

This ſalt may be directly formed by decompoſing the muriate of lime by the means of ammoniac, as Mr. Baumé has practiſed at Paris. But almoſt all the ſal ammoniac which circulates in commerce is brought to us from Egypt, where it is extracted by diſtillation from ſoot, by the combuſtion of the excrements of ſuch animals as feed on ſaline plants.

The

The details of the procefs which is ufed have not been very long known. One of the firft writers who gave a defcription of this operation is father Sicard. He informed us, in 1716, that diftilling veffels were charged with the foot of the excrements of oxen, to which fea falt and camels urine were added.

Mr. Lemaire, conful at Cairo, in a letter written to the Academy of Sciences in 1720, affirms that neither urine nor fea falt is added.

Mr. Haffelquift has communicated to the Academy of Stockholm a confiderably extenfive defcription of the procefs: by which we learn, that the dung of all animals which feed on faline plants is indifcriminately ufed, and that the foot is diftilled, to obtain fal ammoniac.

The dung is dried by applying it againft the walls; and it is burned inftead of wood, in fuch countries as do not poffefs that fuel. The fublimation is performed in large round bottles of one foot and a half diameter, terminating in a neck of two inches in height; and they are filled to within four inches of the neck. The fire is kept up during three times twenty-four hours; the falt is fublimed to the upper part of thefe veffels, where it forms a mafs of the fame figure as the veffels themfelves. Twenty pounds of ſoot afford ſix pounds of ſal ammoniac, according to Rudenſkield.

I was always of opinion that ſal ammoniac might be extracted by treating the dung of the numerous animals which feed on ſaline plants in the plains of La Camargue and La Crau, in the ſame manner; and after having procured, with the greateſt difficulty, two pounds of the ſoot, I extracted from it four ounces of ſal ammoniac. I muſt obſerve, to ſave much trouble to thoſe who may wiſh to follow this branch of commerce, that the dung produced during the ſummer, the ſpring, or the autumn, does not afford this ſalt. I did not know to what circumſtance to attribute the verſatility of my reſults, until I found that theſe animals do not eat ſaline vegetables, excepting at the time when freſh plants cannot be had; and that they are reduced to the neceſſity of having recourſe to ſaline plants only during the three winter months. This obſervation appears to me to be a proof, that marine ſalt is decompoſed in the firſt paſſages; and that the ſoda is modified to the ſtate of ammoniac.

Sal ammoniac is continually ſublimed through the apertures of volcanic mountains. Mr. Ferber found it; and Mr. Sage admitted its exiſtence among volcanic products. It is found in

the

the grottos of Puzzolo, according to Meſſrs. Swab, Scheffer, &c.

It is found in the country of the Calmucs. Model analyſed it.

It is alſo produced in the human body, and exhales by perſpiration in malignant fevers. Mr. Model has proved this fact in his own perſon: for at the time of a violent ſweat which terminated a malignant fever, he waſhed his hands in a ſolution of pot-aſh, and obſerved that a prodigious quantity of alkaline gas was diſengaged.

Sal ammoniac cryſtallizes by evaporation in quadrangular priſms, terminated by ſhort quadrangular pyramids. It is often obtained in rhombic cryſtals by ſublimation. The concave face of the loaves of ſal ammoniac in commerce is ſometimes covered with theſe cryſtals.

This ſalt has a penetrating, acid, urinous taſte. It poſſeſſes a degree of ductility which renders it flexible, and cauſes it to yield to a blow of the hammer. It does not change in the air; which circumſtance renders it probable that our ſal ammoniac is different from that mentioned by Pliny and Agricola, as that attracted humidity. Three parts and a half of water diſſolve one part of ſal ammoniac, at ſixty degrees of Fahrenheit's thermometer; a conſiderable degree of cold is produced by its ſolution.

One hundred parts of ſal ammoniac contain fifty-two parts acid, forty ammoniac, and eight water.

This ſalt is not at all decompoſed by clay; nor by magneſia except with difficulty, and in part only; but it is completely decompoſed by lime and fixed alkalis. The ſulphuric and nitric acids diſengage its acid.

This ſalt is uſed in dyeing, to bring out certain colours. It is mixed with aqua fortis, to increaſe its ſolvent power.

It is uſed in ſoldering; in which operation it poſſeſſes the double advantage of clearing the metallic ſurface, and preventing its oxidation.

CHAP. V.

Concerning the Nitro-muriatic Acid.

THE acid which we call Nitro-muriatic, is a combination of the nitric and muriatic acids.

Our predeceſſors diſtinguiſhed it by the name of Aqua Regia, on account of its property of diſſolving gold.

There are ſeveral known proceſſes for making this mixed acid.

If two ounces of common ſalt be diſtilled with four of nitric acid, the acid which comes over

over into the receiver will be good nitro-muriatic acid.

This is the procefs of Mr. Baumé.

The nitrate of pot-afh may be decompofed by diftilling two parts of muriatic acid from one of this falt: good aqua regia is the product of this operation; and the refidue is a muriate of pot-afh, according to Mr. Cornette.

Boerhaave affirms that he obtained a good aqua regia, by diftilling a mixture of two parts of nitre, three of fulphate of iron or martial vitriol, and five of common falt.

The fimple diftillation of nitre of the firft boiling affords aqua regia; which is employed by the dyers in the folution of tin, for the compofition of the fcarlet dye. This aqua fortis is a true aqua regia: and it is by virtue of the mixture of acids that it diffolves tin; for if it confifted of the nitric acid in a ftate of too great purity, it would corrode and oxide the metal without diffolving it. The dyers then fay that the aqua fortis precipitates the tin; and they correct the acid by diffolving fal ammoniac or common falt in it.

Four ounces of fal ammoniac in powder, diffolved gradually, and in the cold, in one pound of nitric acid, form an excellent aqua regia. An oxigenated muriatic acid gas is dif-

engaged

engaged for a long time; which it is imprudent to attempt to coerce, and which ought to be ſuffered to eſcape by convenient apertures.

Aqua regia is likewiſe formed by mixing together two parts of pure nitric acid and one of muriatic acid.

The very evident ſmell of oxigenated muriatic acid, which is diſengaged in every proceſs which can be adopted to form the acid at preſent in queſtion; and the property which it poſſeſſes, equally with the oxigenated muriatic acid, of diſſolving gold, have led certain chemiſts to infer that, in the mixture of theſe two acids, the muriatic acid ſeized the oxigene of the nitric, and aſſumed the character of oxigenated muriatic acid: ſo that the nitric acid was conſidered as anſwering no other purpoſe than that of oxigenating the muriatic. But this ſyſtem is inconſiſtent; and though the virtues of the muriatic acid are modified by this mixture, and it is oxided by the decompoſition of a portion of the nitric acid, nevertheleſs the two acids ſtill exiſt in the aqua regia: and I am convinced that the beſt made aqua regia, ſaturated with pot-aſh, will afford the ordinary muriate, the oxigenated muriate, and the nitrate. It appears to me that the powerful action of aqua regia depends ſimply on the union of the two acids;

one

one of which is exceedingly well calculated to oxide the metals, and the other diſſolves the oxides or calces with the greateſt avidity.

CHAP. VI.

Concerning the Acid of Borax.

THE acid of borax, more generally known by the name of Homberg's Sedative Salt, is almoſt always afforded by the decompoſition of the borate of ſoda, or borax. But it has been found perfectly formed in certain places; and we have reaſon to hope that we ſhall ſpeedily acquire more accurate information reſpecting its nature.

Mr. Hoefer, director of the Pharmacies of Tuſcany, was the firſt who detected this acid ſalt in the waters of the lake Cherchiajo, near Monte-rotondo, in the inferior province of Sienna: theſe waters are very hot, and they afforded him three ounces of the pure acid in one hundred and twenty pounds of the water. This ſame chemiſt having evaporated twelve thouſand two hundred and eighty grains of the water of the lake of Caſtelnuovo, obtained one hundred and

and twenty grains. He preſumes, moreover, that it might be found in the water of ſeveral other lakes, ſuch as thoſe of Laſſo, Montecerbeloni, &c.

Mr. Sage has depoſited in the hands of the Royal Academy of Sciences ſome acid of borax, brought from the mines of Tuſcany by Mr. Beſſon, who collected it himſelf.

Mr. Weſtrumb found ſedative ſalt in the ſtone called Cubic Quartz of Luneburg. He obtained it by decompoſing this ſtone by the acids of ſulphur, nitre, &c. The reſult of his analyſis is the following:

Sedative ſalt	—	$\frac{6}{10}$
Calcareous earth	—	$\frac{1}{10}$
Mageſia	—	$\frac{1}{10}$
Clay and ſilex	—	$\frac{2}{100}$
Iron	—	$\frac{1}{200}$ to $\frac{2}{200}$

This ſtone, according to the obſervations of Laſſius, has the form of ſmall cubical cryſtals, ſometimes tranſparent, in other ſpecimens milky, and affords ſparks with the ſteel.

The acid of borax is generally found combined with ſoda. It is from this combination that it is diſengaged, and obtained either by ſublimation or cryſtallization.

When it is propoſed to obtain it by ſublimation, three pounds of calcined ſulphate of iron,

iron, and two ounces of borate of soda, are dissolved in three pounds of water. The solution is then filtered, and evaporated to a pellicle; after which the sublimation is performed in a cucurbit of glass with its head. The acid of borax attaches itself to the internal surface of the head, from which it may be swept by a feather.

Homberg obtained it by decomposing of borax with the sulphuric acid. This process succeeded with me wonderfully well. For this purpose I make use of a glass cucurbit with its head, which I place on a sand bath. I then pour upon the borax half its weight of sulphuric acid, and proceed to sublimation. The sublimed acid is of the most beautiful whiteness.

Stahl, and Lemery the younger, obtained the same acid by making use of the nitric and muriatic acids.

To extract the acid of borax by crystallization, the borax is dissolved in hot water, and an excess of sulphuric acid is poured in. A salt is deposited during the cooling on the side of the vessel, in the form of thin round plates, applied one upon the other. This salt, when dry, is very white, very light, and of a silvery appearance. It is the acid of borax.

We are indebted to Geoffroy for this process.

Baron

Baron has added two facts: the firft, that the vegetable acids are equally capable of decompofing borax; and the fecond, that borax may be regenerated by combining the acid of borax with foda.

This acid may be purified by folution, filtration, and evaporation; but it muft be obferved, that a confiderable part is volatilized with the water which flies off in the evaporation.

The acid of borax has a faline cool tafte. It colours the tincture of turnfole, fyrup of violets, &c. red.

One pound of boiling water diffolved no more than one hundred and eighty-three grains, according to Mr. De Morveau.

Alcohol diffolves it more eafily; and the flame which this folution affords is of a beautiful green. This acid, when expofed to the fire, is reduced to a vitriform and tranfparent fubftance, inftead of rifing; which proves, as Rouelle has obferved, that it is only fublimed by favour of the water, with which it forms a very volatile compound.

As moft of the known acids decompofe this acid, and exhibit it in the fame form, it has been thought a juftifiable conclufion that it exifts ready formed in the borax. Mr. Baumé has even affirmed that he compofed this acid by

leaving

leaving a mixture of grey clay, greaſe, and cows dung expoſed to the air in a cellar. But Mr. Wiegleb, after an unſucceſsful labour of three years and a half, thinks himſelf authoriſed to give a formal negative to the French chemiſt.

Mr. Cadet has endeavoured to prove——1. That the acid of borax always retains a portion of the acid employed in the operation. 2. That this ſame acid has ſtill the mineral alkali for its baſis.—Mr. De Morveau has, with his uſual ſagacity, diſcuſſed all the proofs brought forward by Mr. Cadet; he has ſhewn that none of them are concluſive, and that the acid of borax is entitled to retain its place among the chemical elements.

ARTICLE I.

Borate of Pot-aſh.

The acid of borax combined with pot-aſh forms this ſalt. It may be obtained either by the direct combination of theſe two ſeparate principles, or by decompoſing borax by the addition of pot-aſh.

This ſalt, which is yet little known, afforded Mr. Baumé ſmall cryſtals.

The acids diſengage it by ſeizing its alkaline baſe.

ARTI-

ARTICLE II.

Borate of Sòda.

This combination forms Borax, properly ſo called.

It is brought to us from the Indies; and its origin is ſtill unknown*.

The article Borax may be conſulted in Bomare's Dictionary of Natural Hiſtory.

It does not appear that borax was known to the ancients. The chryſocolla, of which Dioſcorides ſpeaks, was nothing but an artificial ſolder compoſed, by the goldſmiths themſelves, with the urine of children and ruſt of copper, which were beaten together in a mortar of the ſame metal.

The word Borax is found for the firſt time in the works of Geber. Every thing which has been written ſince that time concerning borax,

* The origin of borax is very well aſcertained in two Papers, in the ſeventy-ſeventh volume of the Philoſophical Tranſactions, Numbers xxviii. and xxix. It is dug up in a cryſtallized ſtate from the bottom of certain ſalt lakes in a mountainous, barren, volcanic diſtrict, about twenty-five days journey to the eaſtward of Laſſa, the capital of the kingdom of Thibet. T.

is applicable to the ſubſtance which is at preſent known to us by that name.

Borax is found in commerce in three different ſtates.—The firſt is brute borax, tincall, or chryſocolla. It comes to us from Perſia, and is enveloped and ſoiled by a greaſy covering. The pieces of brute borax have almoſt all of them the form of a ſix-ſided priſm, ſlightly flattened, and terminated by a dihedral pyramid. The fracture of theſe cryſtals is brilliant, with a greeniſh caſt. This kind of borax is very impure. It is pretended that borax is extracted from the lake of Necbal, in the kingdom of Grand Thibet. This lake is filled with water during the winter, which exhales in the ſummer; and when the waters are low, workmen enter, who detach the cryſtals from the muddy bottom, and put them into baſkets.

The Weſt Indies contain borax. It is to Mr. Anthony Carera, a phyſician eſtabliſhed at Potoſi, that we are indebted for this diſcovery. The mines of Riquintipa, and thoſe in the neighbourhood of Eſcapa, afford this ſalt in abundance. The natives uſe it in the fuſion of copper ores.

The ſecond kind of borax known in commerce comes from China. It is purer than the preced-

preceding, and has the form of ſmall plates cryſtallized upon one of their ſurfaces, on which the rudiments of priſms may be perceived. This borax is mixed with a white powder, which appears to be of an argillaceous nature.

Theſe ſeveral kinds of borax have been purified at Venice for a long time, and afterwards in Holland; but Meſſrs. Laguiller refine it at preſent in Paris: and this purified borax forms the third kind which is met with in commerce.

In order to purify borax, nothing more is neceſſary than to clear it of the unctuous ſubſtance which ſoils it, and impedes its ſolution.

Crude borax added to a ſolution of mineral alkali, is more completely diſſolved, and may be obtained of conſiderable beauty by a firſt cryſtallization; but it retains the alkali made uſe of: and borax, purified in this manner, poſſeſſes a greater proportion of alkali than in its crude ſtate.

The oily part of borax may be deſtroyed by calcination. By this treatment it becomes more ſoluble, and may in fact be purified in this way. But the method is attended with a conſiderable loſs, and is not ſo advantageous as might be imagined.

The moſt ſimple method of purifying borax, conſiſts in boiling it ſtrongly, and for a long time.

time. This ſolution being filtrated, affords by evaporation cryſtals rather foul, which may be purified by a ſecond operation ſimilar to the foregoing. I have tried all theſe proceſſes in the large way; and the latter appeared to me to be the moſt ſimple.

Purified borax is white, tranſparent, and has a ſomewhat greaſy appearance in its fracture.

It cryſtallizes in hexahedral priſms, terminated by trihedral and ſometimes hexahedral pyramids.

It has a ſtyptic taſte.

It converts ſyrup of violets to a green.

When borax is expoſed to the fire, it ſwells up, the water of cryſtallization is diſſipated in the form of vapour; and the ſalt then becomes converted into a porous, light, white, and opake maſs, commonly called Calcined Borax. If the fire be more ſtrongly urged, it aſſumes a paſty appearance, and is at length fuſed into a tranſparent glaſs of a greeniſh yellow colour, ſoluble in water; and which loſes its tranſparency by expoſure to the air, in conſequence of a white efflorеſcence that forms upon its ſurface.

This ſalt requires eighteen times its weight of water, at the temperature of ſixty degrees of Fahrenheit's thermometer, to diſſolve it. Boiling water diſſolves one-ſixth of its weight.

Barytes and magnefia decompofe borax. Lime-water precipitates the folution of this falt; and if quick-lime be boiled with borax, a falt of fparing folubility is formed, which is the borate of lime.

Borax is ufed as an excellent flux in docimaftic operations. It enters into the compofition of reducing fluxes, and is of the greateft ufe in analyfes by the blow-pipe. It may be applied with advantage in glafs manufactories; for when the fufion turns out bad, a fmall quantity of borax re-eftablifhes it. It is more efpecially ufed in foldering. It affifts the fufion of the folder, caufes it to flow, and keeps the furface of the metals in a foft or clean ftate, which facilitates the operation. It is fcarcely of any ufe in medicine. Sedative falt alone is ufed by fome phyficians; and its name fufficiently indicates its application.

Borax has the inconvenience of fwelling up, and requires the greateft attention on the part of the artift who ufes it in delicate works, more efpecially when defigns are formed with gold of different colours. It has been long a defideratum to fubftitute fome compofition in the room of borax, which might poffefs its advantages without its defects.

Mr. Georgi has publifhed the following procefs:—" Natron, mixed with marine falt and Glauber's falt, is to be diffolved in lime-water; and the cryftals which feparate by the cooling of the fluid may be fet apart. The lixivium of natron is then to be evaporated; and this falt afterwards diffolved in milk. The evaporation affords fcarcely one-eighth of the natron employed, and the refidue may be applied to the fame ufes as borax."

Meffrs. Struve and Exchaquet have proved that the phofphate of pot-afh, fufed with a certain quantity of fulphate of lime, forms an excellent glafs for foldering metals.—See the Journal de Phyfique, t. xxix. p. 78, 79.

ARTICLE III.

Borate of Ammoniac.

This falt is ftill little known. We are indebted to Mr. De Fourcroy for the following indications:—He diffolved the acid of borax in ammoniac, and obtained by evaporation a bed or plate of cryftals connected together, whofe furface exhibited polyhedral pyramids. This falt has a penetrating and urinous tafte; it renders the fyrup of violets green; gradually lofes its cryftalline form, and becomes of a brown colour, by the contact of air." It appears to be of considerable solubility in water. Lime disengages the volatile alkali.

CONCERNING MINERAL WATERS*.

THE name of Mineral Water is given to any water whatever which is sufficiently loaded with foreign principles to produce an effect upon the human body, different from that which is produced by the waters commonly used for drink.

Men, doubtless, were not long in attending to the differences of waters. Our ancestors appear even to have been more strictly attentive than ourselves to procure wholesome drink. It was almost always the nature of the water which

* As mineral waters bear relation to every part of chemistry, their analyses may be indifferently placed at the end of any one of the parts. But as the nature of the principles they contain suppose an acquaintance with the products of the three kingdoms, it is more natural to reserve the article of the mineral waters for the conclusion of a course of chemistry. I have thought proper to change this order for no other reason, than because I foresaw that the third volume of this work would be of too large a size even without it.

deter-

determined their preference in the ſituation of towns, the choice of habitations, and conſequently the union of citizens. The ſmell, the taſte, and more eſpecially the effects of waters upon the animal economy, have been thought ſufficient, during a long time, to determine their nature. We may ſee, in the writings of Hippocrates, how much obſervation and genius are capable of performing in ſubjects of this nature. This great man, of whom it would afford but a very imperfect idea to conſider him merely as the Father of Medicine, was ſo well acquainted with the influence of water upon the human body, that he affirms that the mere quality of their uſual drink is capable of modifying and producing a difference between men; and he recommends to young phyſicians to attend more particularly to the nature of the waters their patients ought to uſe. We ſee that the Romans, who were frequently under the neceſſity of ſettling in parched climates, ſpared no exertions to procure wholeſome water to their colonies. The famous aqueduct which carried the water of Uzes to Niſmes, is an unequivocal proof of this; and we ſtill poſſes ſeveral mineral ſprings at which they formed colonies, for the advantage of the baths.

It was not till near the ſeventeenth century that the application of chemical methods to the examination of waters was firſt made. We are indebted to the preſent revolution of chemiſtry for the degree of perfection to which this analyſis has been carried.

The analyſis of waters appears to me to be neceſſary, in order—

1. That we may not make uſe of any water for drink but ſuch as is wholeſome.

2. That we may become acquainted with thoſe which poſſeſs medicinal virtues, and apply them to the uſes to which they are ſuited.

3. To appropriate to the different works or manufactories that kind of water which is the beſt calculated for their reſpective purpoſes.

4. To correct impure waters, or ſuch as are either impregnated with any noxious principle, or charged with any ſalt.

5. To imitate the known mineral waters, in all places and at all times.

The analyſis of mineral waters is one of the moſt difficult problems of chemiſtry. In order to make a perfect analyſis, it is neceſſary to be aware of all the diſtinctive characters of the ſubſtances which may be held in ſolution in any water. The operator muſt be acquainted with the means of ſeparating from an almoſt inſenſi-

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ble reſidue the different ſubſtances which compoſe it. He muſt be able to appreciate the nature and quantity of the products which are carried off by evaporation; and likewiſe to aſcertain whether certain compounds are not formed by the operations of his analyſis, while others may be decompoſed.

The ſubſtances contained in waters are held either in ſuſpenſion or in ſolution.

1. Thoſe ſubſtances which are capable of being ſuſpended in waters are, clay, ſilex in a ſtate of diviſion, calcareous earth, magneſia, &c.

Thoſe which are ſoluble are, pure air, the carbonic acid, pure or compound alkalis, lime, magneſia, the ſulphates, the muriates, the extractive matter of plants, hepatic gas, &c. The moſt ancient, the moſt general, and the moſt ſimple diviſion of mineral waters, is that which diſtinguiſhes them into cold waters and hot or thermal waters, accordingly as their temperature is the ſame, or exceeds that of common water.

A diviſion founded on the ſeveral qualities of theſe waters, will arrange them in four claſſes.

I. Acidulous or Gaſeous Waters.—Theſe are known by their penetrating taſte; the facility with which they boil; the diſengagement of bubbles

bubbles by fimple agitation, or even by mere ftanding; the property of reddening the tincture of turnfole; the precipitating lime-water, &c.

They are either cold or hot. The firft are thofe of Seltz, of Chateldon, of Vals, of Perols, &c. The fecond are thofe of Vichi, of Mont-d'or, of Chatelguyon, &c.

II. Saline waters, properly fo called.—Thefe are characterifed by their faline tafte, which is modified according to the nature of the falts they contain. The falts moft generally found in waters are, the muriate of magnefia, the fulphates of foda, of lime, &c. Our waters of Balaruc, of Yeufet, &c. are of this nature.

III. Sulphureous Waters.—Thefe waters have long been confidered as holding fulphur in folution. Meffrs. Venel and Monnet oppofed this affertion. Bergmann has proved that moft of thefe waters are merely impregnated with hepatic gas. It appears, however, that there are fome which hold true liver of fulphur in folution, fuch as thofe of Bareges and of Cotteret; whereas the waters of Aix la Chapelle, Montmorency, &c. are of the nature of thofe mentioned by Bergmann. We may, with Mr. De Fourcroy, call the firft by the name of Hepatic Waters, and the latter by the name of Hepatized Waters.

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This claſs is known by the ſmell of rotten eggs which they emit.

IV. Martial Waters.—Theſe have the property of exhibiting a blue colour by the ſolution of pruſſiate of lime: they have beſides a very evident aſtringent taſte. The iron is held in ſolution either by the carbonic or the ſulphuric acid. In the firſt caſe the acid is either in exceſs, and the water has a penetrating ſub-acid taſte, as the waters of Buſſang, Spa, Pyrmont, Pougue, &c.: or the acid is not in exceſs, and conſequently the waters are not acidulous; ſuch are the waters of Forges, Condé, Aumale, &c. Sometimes the iron is combined with the ſulphuric acid, and the water holds in ſolution a true ſulphate of iron. Mr. Opoix admits this ſalt in the waters of Provins; and thoſe of Rougne near Alais are almoſt ſaturated with it. Mineral waters of this quality are frequently found in the vicinity of ſtrata of pyrites. There are ſeveral near Amalou, and in the dioceſe of Uzes.

There are ſome waters which may be placed indiſcriminately in ſeveral of the claſſes. Thus, for example, there are ſaline waters which may be confounded with gaſeous waters, becauſe air is conſtantly deſengaged from them. The waters of Balaruc are of this kind.

We do not comprehend among mineral

waters

waters thoſe which ſuffer gas to eſcape through them, without communicating any characteriſtic property; ſuch as the burning ſpring of Dauphiny, &c.

When the nature of any water is aſcertained, its analyſis may be proceeded upon by the union of chemical and phyſical means. I call thoſe methods phyſical, which are uſed to aſcertain certain properties of water without decompoſing them. Theſe methods are, for the moſt part, ſuch as may be carried into effect at the ſpring itſelf. The appearance, the ſmell, and the taſte afford indications by no means to be neglected.

The limpidity of any water indicates its purity, or at leaſt the accurate ſolution of the foreign principles it may contain; an imperfect tranſparency denotes that foreign ſubſtances are ſuſpended. Good water has no ſmell: the ſmell of rotten eggs denotes liver of ſulphur, or hepatic gas; a ſubtle and penetrating ſmell is proper to acidulous waters; and a fetid ſmell characterizes ſtagnant waters.

The bitterneſs of waters in general depends on neutral ſalts. Lime, and the ſulphates, give them an auſtere taſte.

It is likewiſe of importance to aſcertain the ſpecific gravity of the water, which may be done either by means of the areometer, or by the

the comparifon of its weight with that of an equal volume of diftilled water.

The degree of heat muft likewife be taken by means of a good mercurial thermometer. Thermometers made with fpirits of wine ought to be rejected; becaufe the dilatation, after the thirty-fecond degree of Reaumur, is extreme, and no longer correfponds with the temperature of the water. It is interefting to calculate the time which the water requires to become cool, in comparifon with diftilled water raifed to the fame degree of temperature. Notice muft likewife be taken whether any fubftance exhales, or is precipitated by the cooling.

The obferver ought likewife to enquire whether rains, dry feafons, or other variations of the atmofphere, have any influence on the temperature or quantity of water of the fpring. If thefe caufes act upon the fpring, its virtue cannot but vary exceedingly. This is the caufe why certain mineral waters are more highly charged with their principles in one year than in another; and hence alfo it arifes that certain waters produce wonderful effects in fome years, though in other feafons their effects are trifling. The celebrated De Haen, who analyfed for feveral fucceffive years all the waters in the neighbourhood of Vienna, never found them to contain the fame

principles

principles in the fame proportion. It would therefore be an intereſting circumſtance, if, at the time of taking up or bottling of theſe waters, a ſkilful phyſician were to analyſe them, and publiſh the reſult.

After theſe preliminary examinations have been made at the ſpring, further experiments muſt be made according to the methods of chemiſtry. Theſe experiments ought to be performed at the ſpring itſelf: but if this cannot be done, new bottles may be filled with the water; and, after cloſing them very accurately, they may be carried to the laboratory of the chemiſt, who muſt proceed to examine them by re-agents, and by the method of analyſis.

I. The ſubſtances contained in water are decompoſed by means of re-agents; and the new combinations or precipitates which are formed, immediately point out the nature of the principles contained in the waters. The moſt efficacious and the only neceſſary re-agents are the following:

1. Tincture of turnſole becomes red by its mixture with acidulous waters.

2. Pruſſiate of lime, and that of ferruginous pot-aſh not ſaturated, precipitate the iron contained in a mineral water of a blue colour.

3. The very concentrated ſulphuric acid de-

compoſes moſt neutral ſalts; and forms with their baſes ſalts very well known, and eaſily diſtinguiſhed.

4. The oxalic acid, or acid of ſugar, diſengages lime from all its combinations, and forms with it an inſoluble ſalt.

The oxalate of ammoniac produces a more ſpeedy effect; for, by adding a few cryſtals of this ſalt to water charged with any calcareous ſalt, an inſoluble precipitate is inſtantly formed.

5. Ammoniac or volatile alkali affords a beautiful blue colour with the ſolutions of copper. When this alkali is very pure, it does not precipitate the calcareous ſalt, but decompoſes the magneſian only. In order to have it in a highly cauſtic ſtate, a ſyphon may be plunged in the mineral water, and ammoniacal gas or alkaline air paſſed through it. The water ought to be kept from the contact of the atmoſphere, which otherwiſe might occaſion a precipitation by virtue of its carbonic acid.

6. Lime water precipitates magneſia; and it likewiſe precipitates the iron from a ſolution of ſulphate of iron.

7. The muriate of barytes detects the ſmalleſt particle of ſulphuric ſalts, by the regeneration of ponderous ſpar, which is inſoluble, and falls down.

8. Alco-

8. Alcohol is a good re-agent, on account of its affinity with water.

The nitrates of ſilver and of mercury may likewiſe be employed to decompoſe ſulphuric or muriatic ſalts.

II. Theſe re-agents, indeed, point out the nature of the ſubſtances contained in any water; but they do not exhibit their accurate proportions. For this purpoſe we are obliged to have recourſe to other means.

There are two things to be conſidered in the analyſis of any water—1. The volatile principles. 2. The fixed principles.

1. The volatile principles are carbonic acid gas and hepatic gas. The proportion of carbonic acid may be aſcertained by various proceſſes. The firſt, which has been uſed by Mr. Venel, conſiſts in half filling a bottle with the gaſeous water intended to be analyſed. A bladder is then to be tied upon the neck of the bottle, and the water agitated. The air which is diſengaged inflates the bladder; and by that indication an eſtimate may be made of its quantity. This proceſs is not accurate; becauſe agitation is not ſufficient to diſengage the whole of the carbonic acid. Neither is the evaporation of the water in the pneumato-chemical apparatus much more exact; becauſe the wa-

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ter which rises with the air combines again with it, and the gaseous product consists only of a part of the gas contained in the water. The precipitation by lime-water appears to me to be the most accurate process. Lime-water is poured into a determinate quantity of the water, until it ceases to cause any precipitate. This precipitate being very accurately weighed, $\frac{10}{32}$ parts of the whole must be deducted for the proportion in which water and earth enter into it; and the remainder is the acid contained in this carbonate of lime.

Hepatic gas may be precipitated by the very concentrated nitric acid, according to the experiments of Bergmann.

The oxigenated muriatic acid has been proposed by Scheele; and Mr. De Fourcroy has pointed out the sulphureous acid, the oxides of lead, and other re-agents, to precipitate the small quantity of sulphur held in solution in hepatic gas.

2. Evaporation is commonly used to ascertain the nature of the fixed principles contained in any mineral water. Vessels of earth or porcelain are the only kind suitable to this purpose.

The evaporation must be moderate; for strong ebullition volatilizes some substances, and decomposes others. In proportion as the evaporation

evaporation proceeds, precipitates are afforded, which Mr. Boulduc propofes to take out as they are formed. The celebrated Bergmann advifes evaporation to drynefs, and to analyfe the refidue in the following manner:

1. This refidue muft be put into a fmall phial, and ftrongly agitated with alcohol; after which the fluid muft be filtrated.

2. Upon the refidue pour eight times its weight of cold diftilled water; agitate this, and filter the fluid, after ftanding feveral hours.

3. Laftly, the refidue muft be boiled for a quarter of an hour in five or fix hundred parts of diftilled water, which fluid muft be feparated by filtration.

4. The refidue, which is neither foluble in water nor in alcohol, muft then be moiftened, and expofed for feveral days to the fun: by this treatment, the iron which it may contain, rufts. It muft then be digefted in diftilled vinegar, which diffolves lime and magnefia; and this folution, evaporated to drynefs, affords either an earthy falt in filaments which are not deliquefcent, or a deliquefcent falt; which laft has magnefia for its bafe. The infoluble refidue contains iron and clay, which are to be diffolved in the muriatic acid. The iron is firft to be precipi-

precipitated by the pruſſiate of lime; and afterwards the clay by another alkali.

The ſalts which the alcohol has diſſolved, are the muriates of magneſia and of lime. They are eaſily known by decompoſing them by the ſulphuric acid.

With reſpect to the ſalts diſſolved in the cold water, they muſt be ſlowly cryſtallized; and their form, and other obvious qualities, will ſhew what they are.

The ſolution by boiling water contains nothing but ſulphate of lime.

When the analyſis of any water has been well made, the ſyntheſis becomes eaſy; and the compoſition or perfect imitation of mineral waters is no longer a problem inſoluble to chemiſts. What, in fact, is a mineral water? It is rain water, which, filtering through the mountains, becomes impregnated with the various ſoluble principles it meets with. Why, therefore, when once we know the nature of theſe principles, can it not be poſſible to diſſolve them in common water, and to do that which nature itſelf does? Nature is inimitable only in its vital operations; we may imitate its effects perfectly in all other proceſſes: we may even do better; for we can at pleaſure vary the temperature and the proportions of the conſtitu-

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ent parts. The machine of Nooth, improved by Parker, may be made uſe of to compoſe any gaſeous mineral water, whether acidulous or hepatic; and nothing is more eaſy than to imitate ſuch waters as contain only fixed principles.

THE END OF THE FIRST VOLUME.